Memorandum

To: *Stephanie Vaughn, EPA Region 2*
Elizabeth Buckrucker, USACE

From: *Frank Tsang and Scott Kirchner*

Date: *October 31, 2014*

Subject: *2013 Low Resolution Coring Second Supplemental Split Sample Data Comparison for the Lower Passaic River Study Area*

At the request of the United State Environmental Protection Agency (EPA) and the United States Army Corps of Engineers (USACE), CDM Federal Programs Corporation (CDM Smith) collected oversight split sediment samples as part of the Lower Passaic River (LPR) Restoration Project remedial investigation conducted by the Cooperating Parties Group (CPG). This memorandum presents the comparison of the EPA oversight team's split sample results to the CPG's sample results and discusses the differences in the data pairs. In this document, samples are referred to as either CPG samples or EPA split samples for clarity.

The split sample comparison consisted of 25 sample pairs, which were evaluated for dioxins/furans, pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), total organic carbon (TOC), and metals analysis. Thirty-two out of 48 compounds (67%) evaluated in the EPA and CPG split samples comparison are comparable. Only the 22 chemicals listed below are not comparable.

- Dioxins/Furans: 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HPCDD), 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), octachlorodibenzofuran (OCDF), total heptachlorodibenzo-p-dioxin (total HPCDD), and total tetrachlorodibenzo-p-dioxin (total TCDD)
- Pesticides: 2,4'-dichlorodiphenyltrichloroethane (2,4'-DDT), 4,4'-dichlorodiphenyltrichloroethane (4,4'-DDT), and dieldrin
- PCBs: 3,3',4,4'-tetrachlorobiphenyl (PCB 77), 3,3',4,4',5-pentachlorobiphenyl (PCB 126), 2,3,3',4,4',5-hexachlorobiphenyl (PCB 156) plus 2,3,3',4,4',5'-hexachlorobiphenyl (PCB 157), and total polychlorinated biphenyls (total PCBs)
- PAHs: anthracene, benzo(a)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene
- Metals: cadmium, chromium, lead, and mercury
- Total Organic Carbon

Oversight Program

Oversight was conducted in accordance with the Final Quality Assurance Project Plan (QAPP), Addendum 10, Low Resolution Coring Supplemental Sampling for the Lower Passaic River Restoration Project (CDM Smith 2012). The split sample program consisted of 25 sediment split samples collected from the study area.

Data Comparison Methodology

The CPG and EPA split sample data were evaluated for potential differences by plotting selected analytes listed on Table 1. For each of the following three plots, data are plotted on the figures evaluated only for the cases where both sample pairs are detected.

- Line Plot: The concentrations measured by both analytical programs for the detected paired samples were plotted against the same axes. The graph depicts the relative magnitudes and patterns of concentrations.

- Bivariate Scatter Plot: CPG sample concentration was plotted as a function of EPA sample concentration for each detected pair. The bivariate scatter plot illustrates the relationship between EPA and CPG data. Also included on the graph is a line which depicts a 1:1 ratio of concentration of EPA and CPG sample. The bivariate scatter plot can be used to identify potential systematic bias when data points fall consistently above or below the 1:1 line.

- Percent Difference Plot: The percent difference (%D) was defined as the difference between concentration for detected data pairs, divided by the concentration of EPA sample (Equation 1).

  $$\% D = \frac{(R_{EPA} - R_{CPG})}{(R_{EPA})}(100) \qquad \text{(Equation 1)}$$

  Consequently, a negative %D indicates a CPG result that is higher than the EPA result, while a positive %D indicates a CPG result that is lower than the EPA result. This plot provides a visual indication of the extent of positive and negative differences between the two data pairs. The red dashed lines on the plot correspond to the criteria of 40%D and -67%D. These criteria correspond to 50% relative percent difference (RPD) (the CPG's field duplicate acceptance criterion), converted to %D values. The term of %D is commonly used when one of the two values is known or accepted, whereas RPD is more commonly used when both values are uncertain. The sample data in this graph was represented with the EPA result as the known value and the CPG result as the unknown value.

In addition to the preparation of data comparison plots on the figures, the tests described below were also conducted for CPG and EPA data pairs and presented in Table 1.

- Average Ratio: The ratios of the CPG results to EPA results were calculated for each detected data pair. The average ratio and standard deviation were calculated for each compound. An average ratio above one indicates that the CPG results were detected higher than the EPA results, while an average ratio below one indicates that the CPG results were detected lower than the EPA results.

- Percent Difference: The calculated %D values were evaluated against the acceptance criteria of greater than or equal to -67%, or less than or equal to 40% (equivalent to less than or equal to 50% RPD).
- Statistical Test: The statistical tests were performed to calculate *p*-values. The *p*-value is an indicator of the presence of a difference between the data pairs. A *p*-value of less than 0.05 indicates a statistically significant difference between the two data sets.
  - Wilcoxon Signed Rank (WSR) Test: The WSR test was used to calculate *p*-values for all detected sample pairs.
  - Paired Prentice-Wilcoxon (PPW) Test: The PPW test was performed to allow inclusion of the left-censored (nondetected) data pairs. The elimination of data pairs containing nondetected values is essentially equivalent to ignoring potentially substantial information contained within these nondetect-containing data pairs, and may lead to biased results. The PPW test relies on survival analysis computations as detailed in O'Brien and Fleming (1987) and is considered the standard test for the case of censored matched pairs (Helsel 2005).

The data comparison plots are depicted in Figures 1 through 48. Results for the three comparison criteria (average ratio, %D, and statistical tests) are presented in Table 1. The numbers of split sample pairs are listed for each compound along with the number of pairs which had detected results for both samples. The average ratio of results of CPG sample to those of EPA sample results are reported with the standard deviation of the ratios. The %D results are summarized by reporting the percentage of data pairs that exceeded the acceptance criteria (40% and -67%). Also included are the *p*-values calculated by the WSR test and the PPW test.

An overall evaluation of the split sample data is based on the result of the three comparison criteria, where each compound has a rating of "Same" or "Different". The data pairs are considered comparable or "Same" if at least two of the three criteria are met. The comparison criteria for each compound are listed below.

- Average Ratio: Average ratio of CPG to EPA results within 0.70 to 1.30.
- Percent Difference: Less than 16% of the data pairs exceed the acceptance criteria of -67% to 40%.
- Statistical Test (WSR Test and PPW Test): *p*-Values greater than or equal to 0.05 are within acceptance limits, indicating there is no significant statistical difference between the data sets. When WSR test and PPW test draw different conclusions:
  - The conclusions of the PPW test would be used for data sets that include nondetects since PPW test is capable of handling nondetects.
  - The conclusions of the WSR test would be used for data sets that include all detected sample pairs especially if potential outliers are present. The WSR test is much less sensitive to outliers compared to the PPW test.

Results of data comparison of CPG and EPA split samples are summarized below and presented in Table 1 and Figures 1 through 48.

Dioxins/Furans

There were eight dioxin/furan compounds evaluated for the three comparison criteria. The data pairs for five compounds, 1,2,3,4,6,7,8-HPCDD, 2,3,7,8-TCDD, OCDF, total HPCDD, and total TCDD, were not comparable (Table 1). From examination of individual sample pairs, the calculated high average ratios were influenced by several high detections which differed greatly between these two data pairs. The majority of detections were within %D criteria as shown in Figures 1 through 8. The WSR and PPW tests results for 1,2,3,4,6,7,8-HPCDD and total HPCDD differed because there is a potential outlier (13B-0564-G2AS). If the sample pairs for 13B-0564-G2AS were removed from the data sets, the p-values for both WSR and PPW tests were less than 0.05. Therefore, the sample pairs are statistically different.

Pesticides

The data pairs for all pesticide compounds were comparable, except 2,4’-DDT, 4,4’-DDT, and dieldrin. The three compounds failed to meet %D criteria and PPW test (Table 1). Figures 9 through 16 show the data comparison plots for eight of the pesticide compounds evaluated. The WSR and PPW tests results for 4,4'-dichlorodiphenyldichloroethylene and alpha-chlordane differed probably because there is a potential outlier (13B-0564-G2AS). However, the conclusion from the PPW test is preferred over the WSR test because there are nondetects in the data sets. Therefore, these two compounds were considered as comparable.

Polychlorinated Biphenyls

Four of the eleven compounds evaluated by the three comparison criteria were found to be different in data pairs (Table1). They are PCB 77, PCB 126, PCB 156 plus PCB 157, and total PCBs. The majority of detections were within %D criteria. The bivariate scatter plots in Figures 17 through 27 show the predominant high bias of CPG results relative to EPA results. The total PCB results were also found to be different even though the PPW test p-value is slightly greater than 0.05. However, due to potential outlier, the conclusion from the WSR test is used.

Polycyclic Aromatic Hydrocarbons

Of the nine evaluated PAH compounds, anthracene, benzo(a)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene were considered different in data pairs. All compounds failed to meet %D criterion as shown in Figures 28 through 36, but all compounds meet the average ratio criterion. The data pair for the five compounds was considered statistically different based on both WSR and PPW tests. The WSR and PPW tests results for anthracene differed because there is a potential outlier (13B-0531-C2CS). Therefore, the conclusion from the WSR test is used.

Metals

Split sample data was evaluated for eleven metals, and the results were found to be comparable, except for cadmium, chromium, lead, and mercury. Figures 37 through 47 show the statistical plots for metals.

Cadmium and mercury did not meet the average ratio and %D comparison criteria. The data pair for cadmium and lead were considered statistically different based on both WSR and PPW tests. The WSR and PPW tests results for chromium and mercury differed because there is a potential outlier (13B-0564-G2AS). Therefore, the conclusion from the WSR test is used since it is less sensitive to outliers.

Two of the mercury results seem to be incorrectly labelled by the laboratory as 13B-0503-C2AS-C and 13B-0503-C3CS-C instead of 13B-0559-C2AS-C and 13B-0559-C3CS-C, respectively. Sample 13B-0503-C2AS-C has the same sample date and time as 13B-0559-C2AS-C. Therefore, it is concluded that these are the same sample. The same goes for 13B-0503-C3CS-C. The database is corrected based on this assumption. In addition, there is no EPA split sample result for mercury corresponding to sample 13B-0521-C3AS. There is an EPA mercury result for sample 13B-0521-C2AS-C. This sample was collected at the same station, same depth interval, but different core. For the split sample comparison, 13B-0521-C2AS-C sample is used as a split sample for 13B-0521-C3AS.

Total Organic Carbon

The results for TOC were not comparable for the two data pairs. The CPG data are usually much higher than the EPA data (Figure 48). The statistical tests also indicated that the data was statistically different.

Similar to mercury, there are no EPA split sample results for TOC corresponding to sample 13B-0530-C3AS and 13B-0530-C3BS. Instead, there are EPA samples 13B-0530-C4AS-C and 13B-0530-C4BS-C which were collected at the same station, same depth interval, but different core. For the split sample comparison, 13B-0530-C4AS-C is used as a split sample for 13B-0530-C3AS, while 13B-0530-C4BS-C is used as a split sample for 13B-0530-C3BS.

Table

Table 1 - 2013 Low Resolution Coring Second Supplemental Split Sample Data Comparison Summary

Figures

Figures 1 through 8:	Statistical Plots of Dioxin/Furan Concentrations
Figures 9 through 16:	Statistical Plots of Pesticide Concentrations
Figures 17 through 27:	Statistical Plots of Polychlorinated Biphenyl Concentrations
Figures 28 through 36:	Statistical Plots of Polycyclic Aromatic Hydrocarbon Concentrations
Figures 37 through 47:	Statistical Plots of Metal Concentrations
Figure 48:	Statistical Plot of Total Organic Carbon Concentrations

References

CDM Smith. 2012. Final Quality Assurance Project Plan (QAPP), Addendum No. 10, Low Resolution Coring Second Supplemental Sampling.

Helsel, D.R. 2005. Nondetects and Data Analysis: Statistics for Censored Environmental Data. Wiley-Interscience.

O'Brien, P.C. and T.R. Fleming. 1987. A Paired Prentice-Wilcoxon Test for Censored Paired Data. Biometrics 43: 169-180.

Table 1 2013 Low Resolution Coring Second Supplement Split Sampling Data Comparison Summary
Lower Passaic River Study Area

Parameter	Number of Split Sample Pairs	Number of Split Sample Pairs with Detected Concentrations	Comparison Criteria					Overall Split Sample Comparison (Same or Different) (6)
			Average Ratio of CPG to EPA (for detected pairs) (1)	Percent Difference (for detected pairs) (2)	Statistical Tests			
					p-value		Statistical Difference (Yes or No) (5)	
					Wilcoxon Signed Rank test (3)	Paired Prentice Wilcoxon test (4)		
Dioxins/Furans								
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	25	25	**1.52 ± 3.11**	8% (Within Criteria)	**0.037**	0.761	**Yes**	**Different**
1,2,3,4,6,7,8-Heptachlorodibenzofuran	25	25	1.07 ± 0.51	**20% (Outside Criteria)**	0.201	0.424	No	Same
2,3,7,8-Tetrachlorodibenzo-p-dioxin	25	23	**30.98 ± 143.4**	**26% (Outside Criteria)**	0.820	0.525	No	**Different**
2,3,7,8-Tetrachlorodibenzofuran	25	24	1.19 ± 1.6	13% (Within Criteria)	0.113	0.889	No	Same
Octachlorodibenzo-p-dioxin	25	25	**1.74 ± 3.87**	4% (Within Criteria)	0.139	0.685	No	Same
Octachlorodibenzofuran	25	24	**1.44 ± 1.16**	**25% (Outside Criteria)**	0.284	0.337	No	**Different**
Total Heptachlorodibenzo-p-dioxin	25	25	**1.49 ± 3.14**	8% (Within Criteria)	**0.008**	0.711	**Yes**	**Different**
Total Tetrachlorodibenzo-p-dioxin	25	22	**4.39 ± 15.59**	**18% (Outside Criteria)**	0.603	0.257	No	**Different**
Pesticides								
2,4'-dichlorodiphenyldichloroethane (2,4'-DDD)	25	22	0.88 ± 0.31	**18% (Outside Criteria)**	0.105	0.053	No	Same
2,4'-dichlorodiphenyldichloroethylene (2,4'-DDE)	25	22	**1.65 ± 3.57**	5% (Within Criteria)	0.051	0.890	No	Same
2,4'-dichlorodiphenyltrichloroethane (2,4'-DDT)	25	9	**0.6 ± 0.36**	**44% (Outside Criteria)**	**0.044**	**0.001**	**Yes**	**Different**
4,4'-dichlorodiphenyldichloroethane (4,4'-DDD)	25	22	0.92 ± 0.33	14% (Within Criteria)	0.144	0.080	No	Same
4,4'-dichlorodiphenyldichloroethylene (4,4'-DDE)	25	23	1.26 ± 1.72	9% (Within Criteria)	**0.027**	0.986	No	Same
4,4'-dichlorodiphenyltrichloroethane (4,4'-DDT)	25	22	**1.62 ± 3.71**	**59% (Outside Criteria)**	0.173	**0.024**	**Yes**	**Different**
alpha-Chlordane	25	23	0.88 ± 0.38	**17% (Outside Criteria)**	**0.004**	0.071	No	Same
Dieldrin	25	23	0.83 ± 0.37	**26% (Outside Criteria)**	**0.005**	**0.008**	**Yes**	**Different**
Polychlorinated Biphenyls (PCBs)								
3,3',4,4'-Tetrachlorobiphenyl (PCB 77)	25	24	**2.53 ± 5.46**	**17% (Outside Criteria)**	0.089	0.119	No	**Different**
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	25	15	**1.98 ± 3.31**	13% (Within Criteria)	0.065	0.132	No	Same
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	25	24	**1.58 ± 2.55**	13% (Within Criteria)	0.184	0.235	No	Same
2,3,4,4',5-Pentachlorobiphenyl (PCB 114)	25	22	**1.81 ± 3.32**	14% (Within Criteria)	0.050	0.128	No	Same
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	25	24	**1.58 ± 2.47**	8% (Within Criteria)	0.149	0.231	No	Same
2',3,4,4',5-Pentachlorobiphenyl (PCB 123)	25	23	**1.72 ± 3.13**	9% (Within Criteria)	0.207	0.264	No	Same
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	25	12	1.26 ± 0.49	**25% (Outside Criteria)**	0.170	**0.040**	**Yes**	**Different**
2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156) + 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	25	24	**1.95 ± 3.52**	13% (Within Criteria)	**0.003**	**0.048**	**Yes**	**Different**
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	25	23	**1.92 ± 3.71**	9% (Within Criteria)	**0.009**	0.077	No	Same
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	25	22	**1.8 ± 3.45**	9% (Within Criteria)	0.661	0.245	No	Same
Total PCBs	25	25	**1.39 ± 1.55**	8% (Within Criteria)	**0.024**	0.189	**Yes**	**Different**
Polycyclic Aromatic Hydrocarbons (PAHs)								
Anthracene	25	25	1.07 ± 1.17	**40% (Outside Criteria)**	**0.041**	0.076	**Yes**	**Different**
Benzo(a)anthracene	25	24	0.86 ± 0.43	**38% (Outside Criteria)**	**0.027**	**0.017**	**Yes**	**Different**
Benzo(a)pyrene	25	25	0.92 ± 0.39	**28% (Outside Criteria)**	0.197	0.099	No	Same
Chrysene	25	23	0.94 ± 0.4	**26% (Outside Criteria)**	0.166	0.095	No	Same
Fluoranthene	25	24	0.81 ± 0.39	**33% (Outside Criteria)**	**0.008**	**0.005**	**Yes**	**Different**
Indeno(1,2,3-cd)pyrene	25	25	0.74 ± 0.28	**36% (Outside Criteria)**	**0.003**	**0.002**	**Yes**	**Different**
Naphthalene	25	22	1.01 ± 0.86	**50% (Outside Criteria)**	0.217	0.166	No	Same
Phenanthrene	25	24	1.18 ± 0.9	**29% (Outside Criteria)**	0.247	0.177	No	Same
Pyrene	25	24	0.79 ± 0.37	**38% (Outside Criteria)**	**0.008**	**0.005**	**Yes**	**Different**
Metals								
Arsenic	25	25	1.15 ± 1.24	16% (Within Criteria)	0.989	0.454	No	Same
Barium	25	25	1.3 ± 0.88	12% (Within Criteria)	0.135	0.093	No	Same
Cadmium	25	20	**4.11 ± 11.54**	**30% (Outside Criteria)**	**0.002**	**0.021**	**Yes**	**Different**
Chromium	25	25	**1.7 ± 3.06**	4% (Within Criteria)	**0.034**	0.122	**Yes**	**Different**
Cobalt	25	25	1.21 ± 0.7	4% (Within Criteria)	**0.045**	0.117	**Yes**	Same
Copper	25	25	**1.46 ± 1.99**	12% (Within Criteria)	0.184	0.321	No	Same
Iron	25	25	1.13 ± 0.63	4% (Within Criteria)	0.989	0.468	No	Same
Lead	25	25	**1.6 ± 1.39**	16% (Within Criteria)	**<0.001**	**0.004**	**Yes**	**Different**
Nickel	25	25	1.1 ± 0.75	8% (Within Criteria)	0.572	0.933	No	Same
Zinc	25	25	**1.31 ± 1.23**	8% (Within Criteria)	0.106	0.114	No	Same
Mercury	25	25	**2.18 ± 3.86**	**32% (Outside Criteria)**	**0.001**	0.066	**Yes**	**Different**
Organic Carbons								
Total Organic Carbon	25	25	**3.05 ± 2.56**	**64% (Outside Criteria)**	**<0.001**	**<0.001**	**Yes**	**Different**

Results outside acceptance criteria are **bolded.**

Notes:
(1) Average ratio (criteria: 0.70-1.30) with standard deviation .
(2) Percent difference criteria: no more than 16% of split samples outside of -67 to 40 percent difference.
(3) Wilcoxon Signed Rank test was employed at significance level (p) of 0.05.
(4) Paired Prentice Wilcoxon test was employed at significance level (p) of 0.05.
(5) Statistical difference was based on Paired Prentice Wilcoxon test when they are at least one nondetected concentration.
Otherwise, it was based on Wilcoxon Signed Rank test to handle potential outliers.
(6) If there are at least two of the three criteria (average ratio, percent different and statistical difference) met,
the overall split sample comparison would be labeled "same". Otherwise, it would be "different".

Abbreviations:
CPG = Cooperating Parties Group
EPA = United States Environmental Protection Agency

Figure 1a: Line Plot of 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin Concentrations

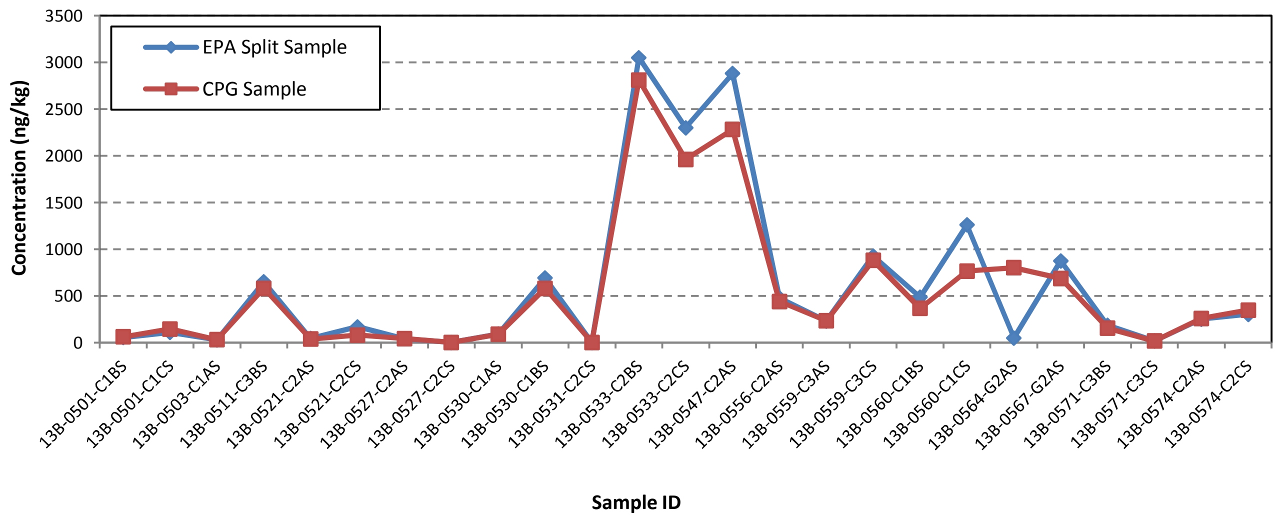


Figure 1b: Bivariate Scatter Plot of 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin Concentrations

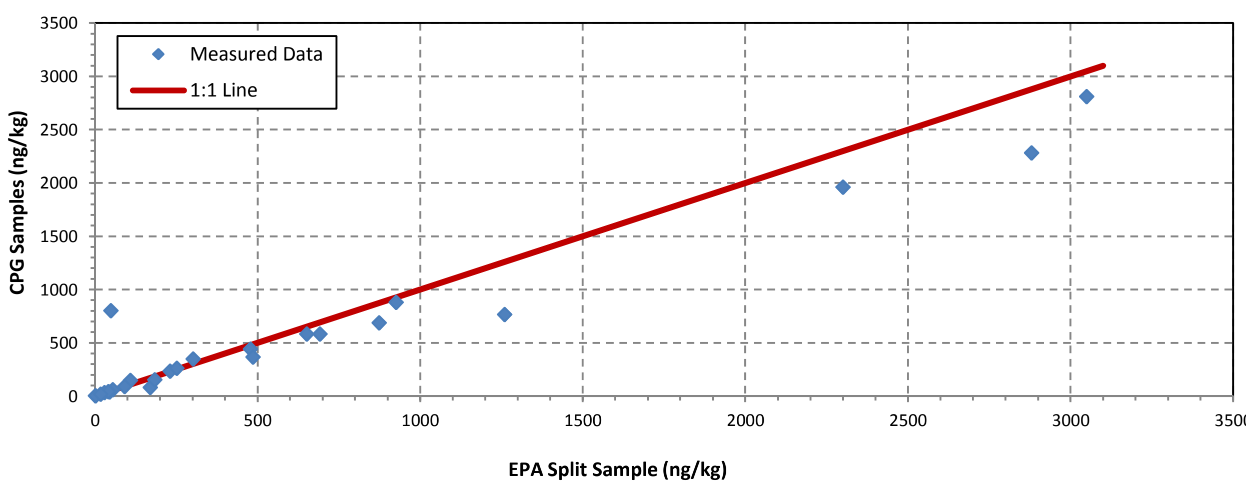
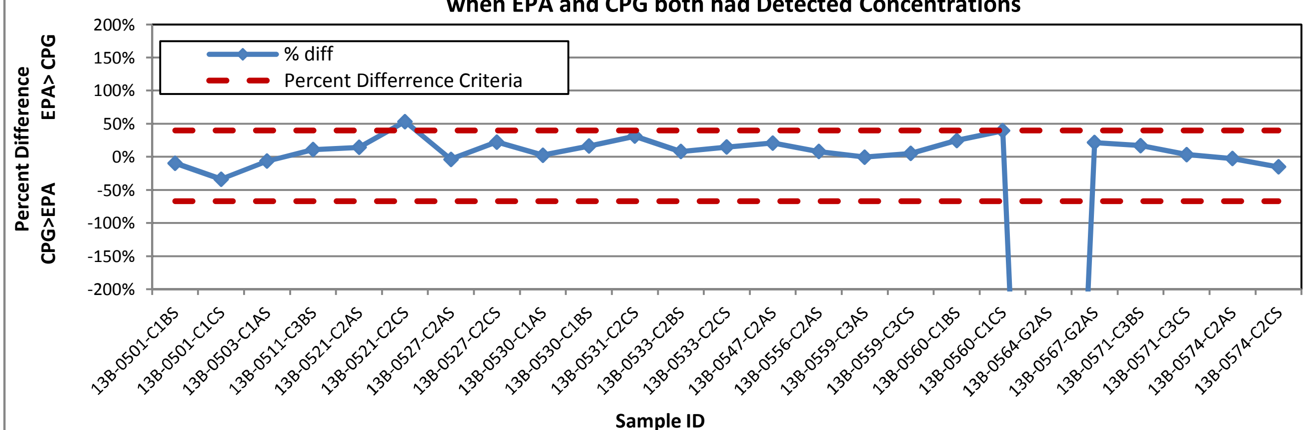


Figure 1c: Line Plot of 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin Concentrations	Figure 1

ng/kg - nanogram per kilogram

Figure 2a: Line Plot of 1,2,3,4,6,7,8-Heptachlorodibenzofuran Concentrations

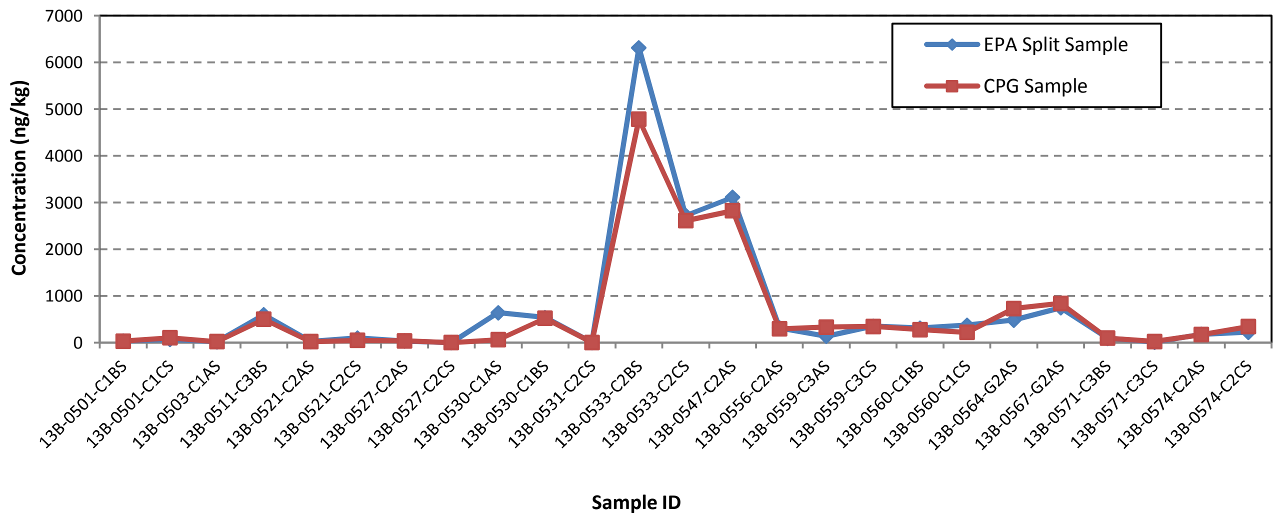


Figure 2b: Bivariate Scatter Plot of 1,2,3,4,6,7,8-Heptachlorodibenzofuran Concentrations

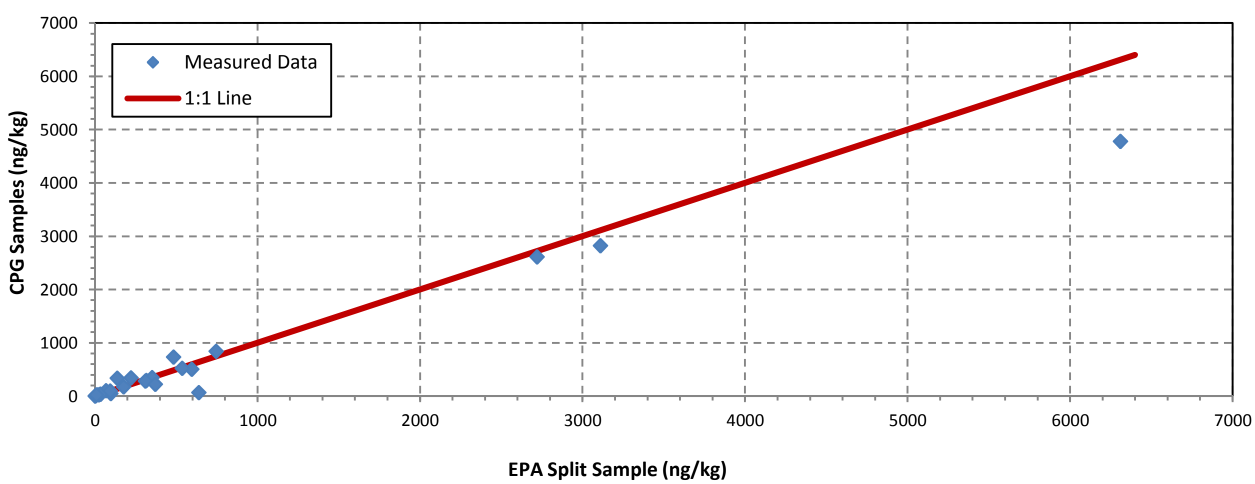
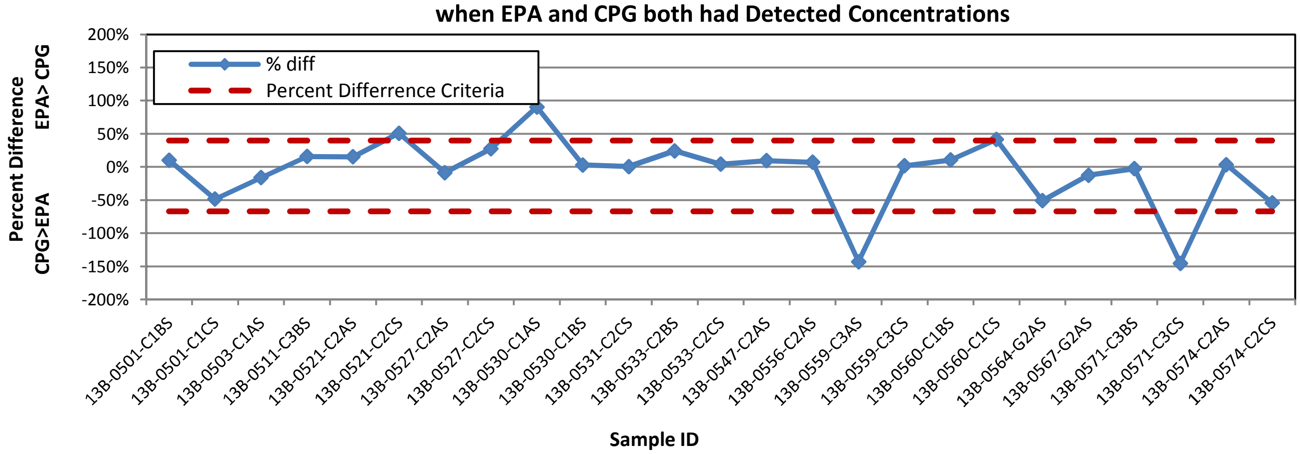


Figure 2c: Line Plot of 1,2,3,4,6,7,8-Heptachlorodibenzofuran Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers®	**Statistical Plots of 1,2,3,4,6,7,8-Heptachlorodibenzofuran Concentrations**	**Figure 2**

ng/kg - nanogram per kilogram

Figure 3a: Line Plot of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Concentrations

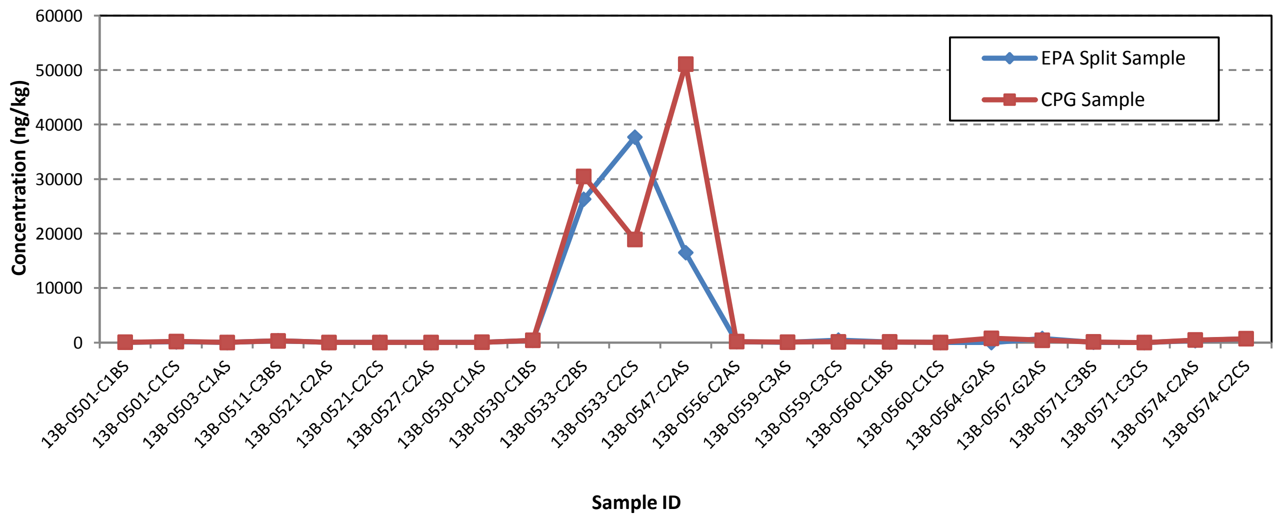


Figure3b: Bivariate Scatter Plot of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Concentrations

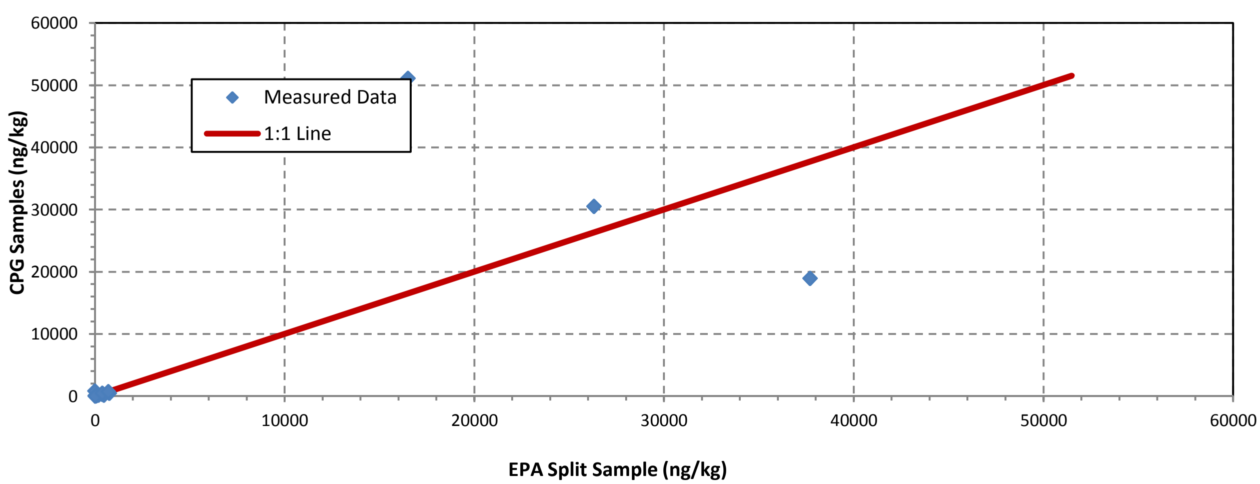
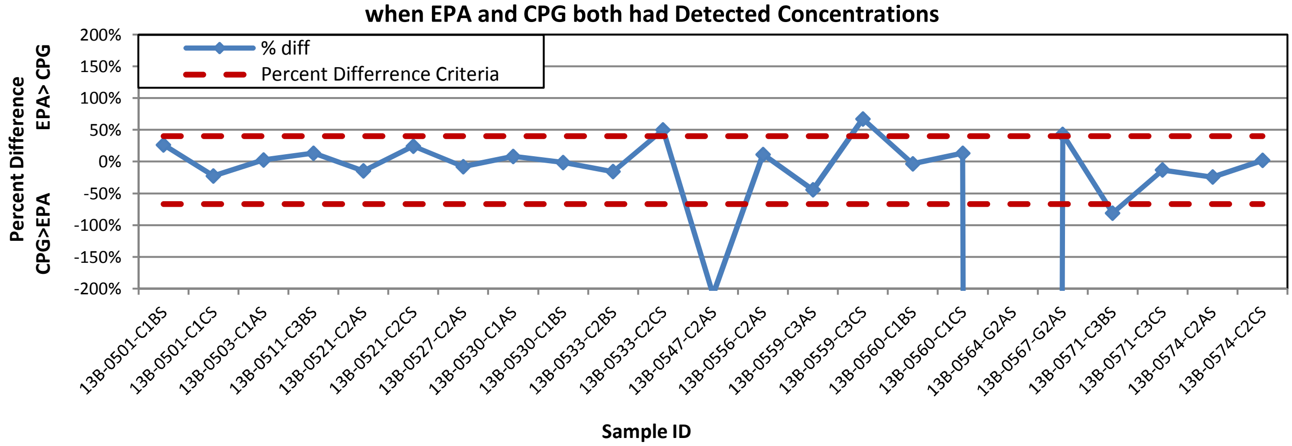


Figure 3c: Line Plot of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Percent Differences when EPA and CPG both had Detected Concentrations



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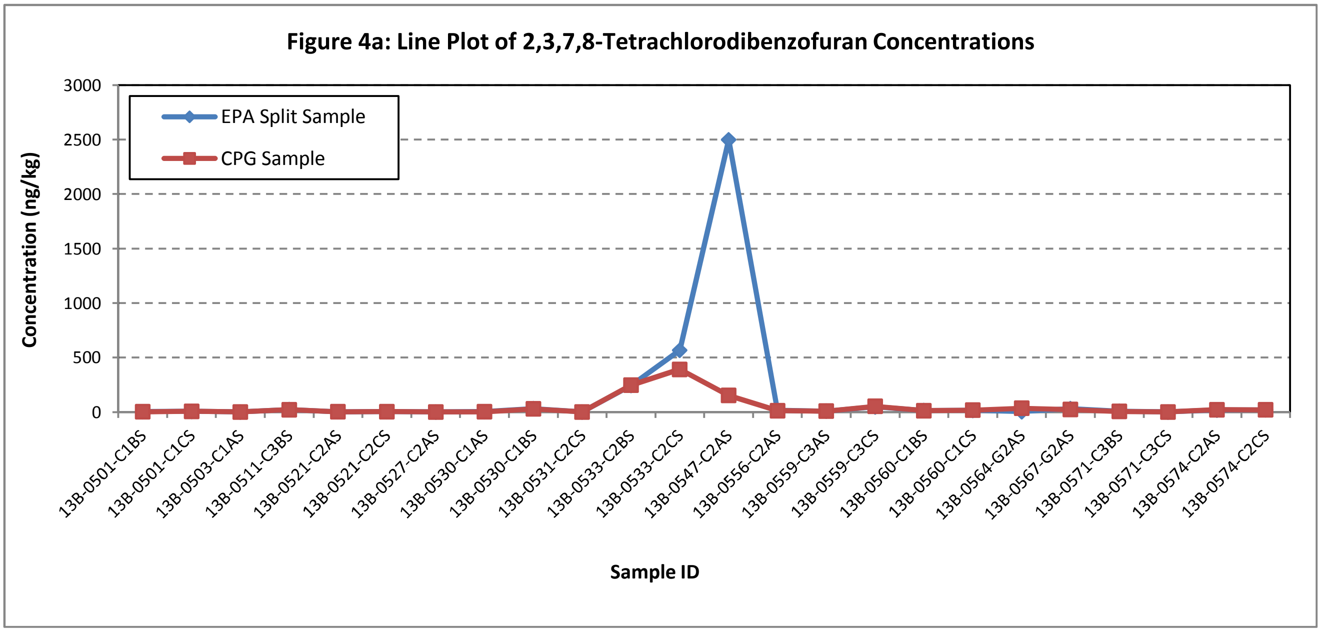
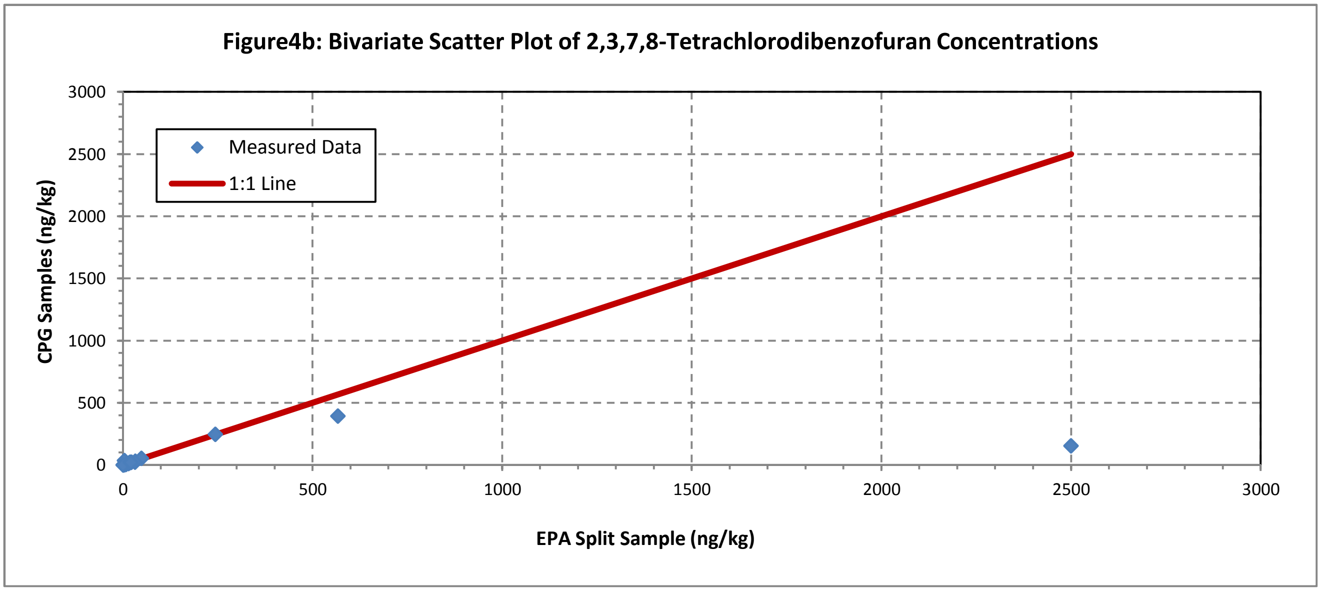
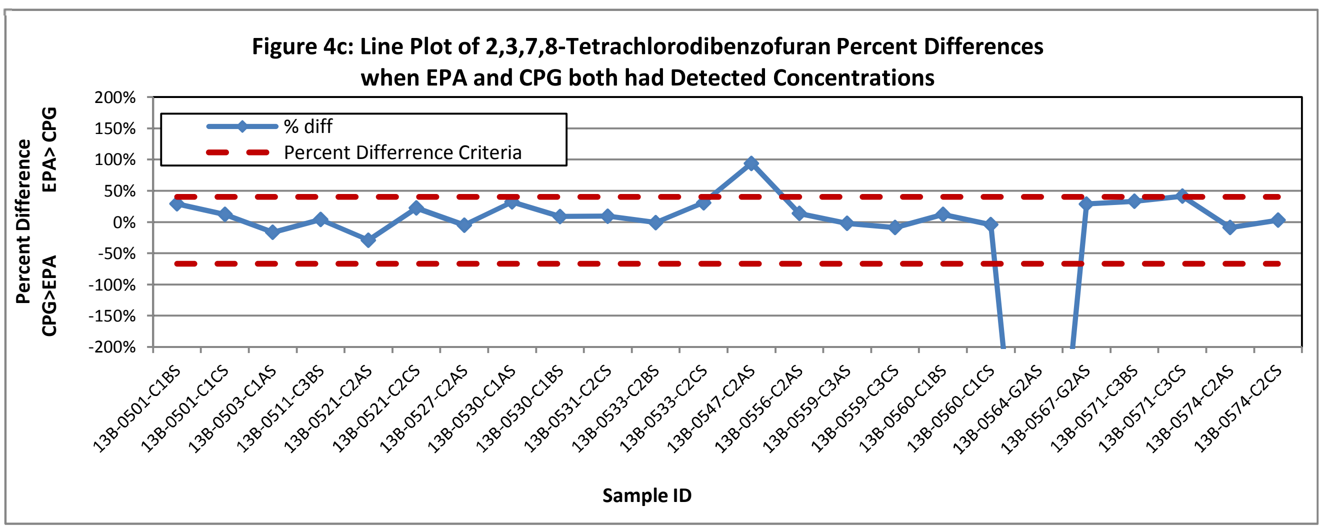
	Statistical Plots of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Concentrations	**Figure 3**

ng/kg - nanogram per kilogram

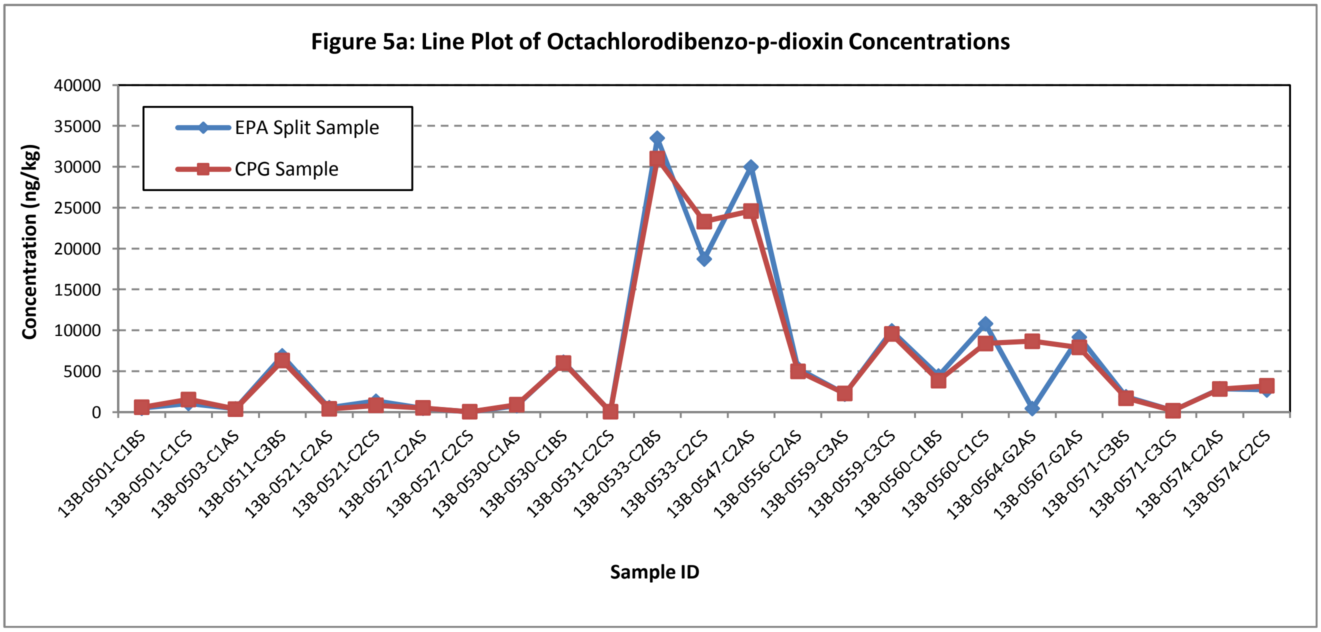


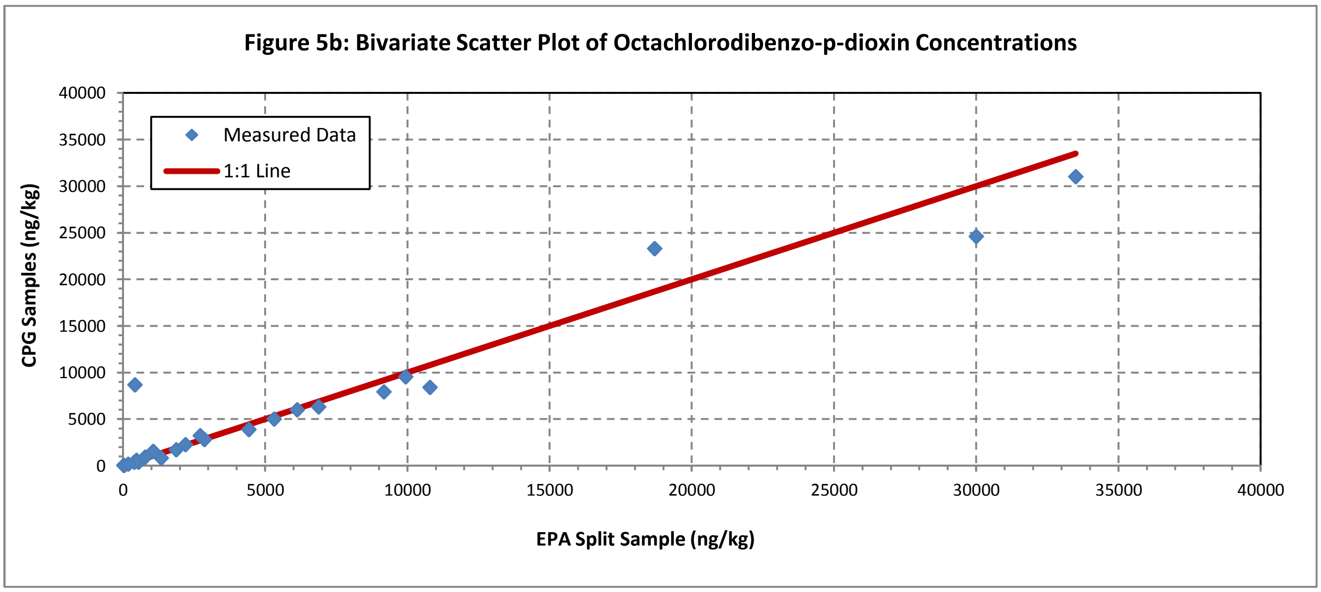


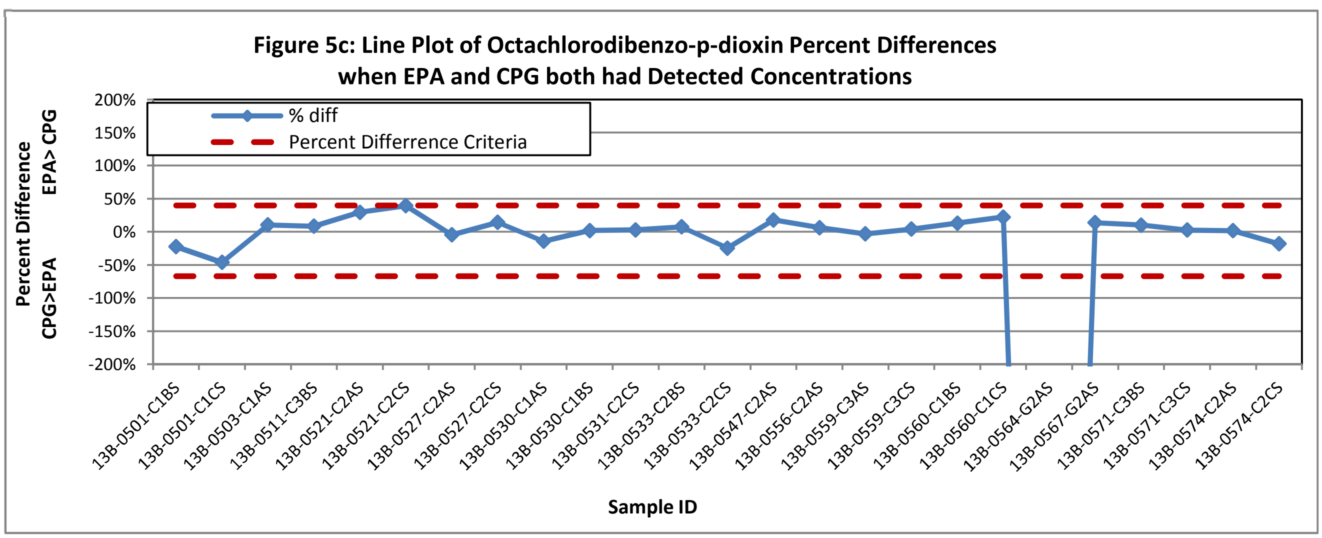


US Army Corps of Engineers®	**Statistical Plots of 2,3,7,8-Tetrachlorodibenzofuran Concentrations**	**Figure 4**

ng/kg - nanogram per kilogram







US Army Corps of Engineers®	**Statistical Plots of Octachlorodibenzo-p-dioxin Concentrations**	**Figure 5**

ng/kg - nanogram per kilogram

Figure 6a: Line Plot of Octachlorodibenzofuran Concentrations

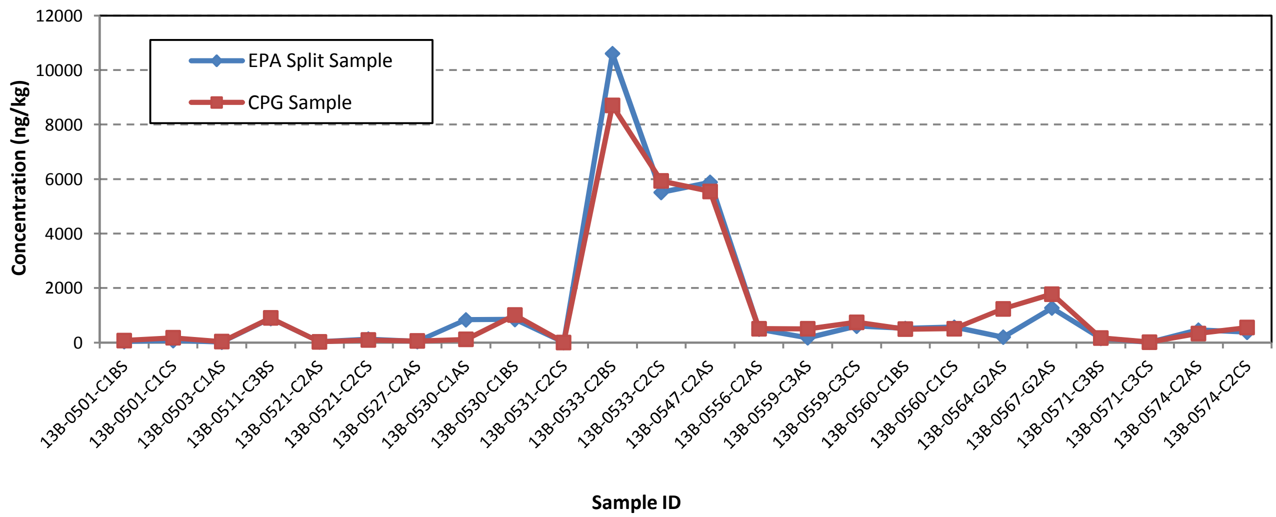


Figure 6b: Bivariate Scatter Plot of Octachlorodibenzofuran Concentrations

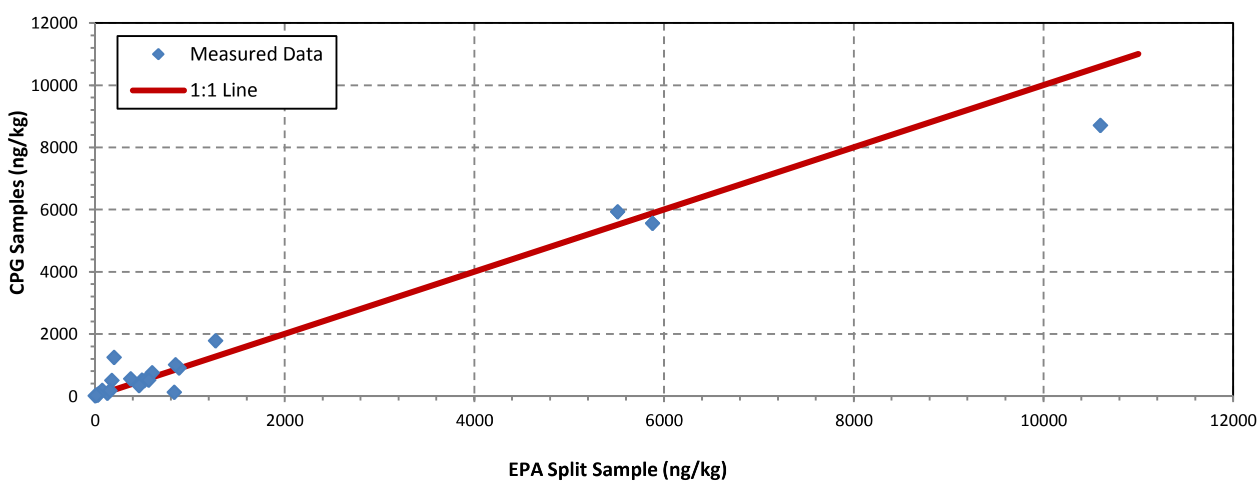
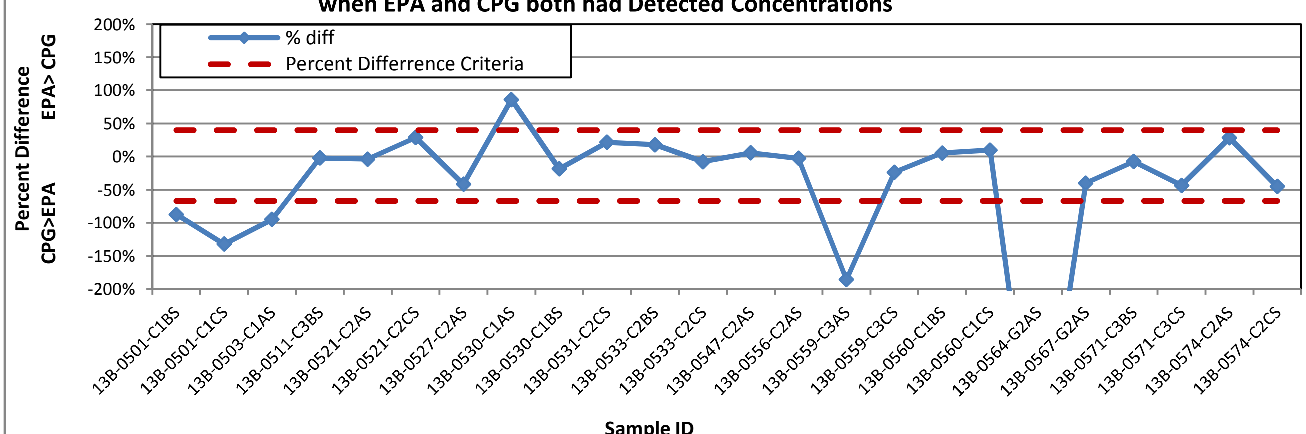


Figure 6c: Line Plot of Octachlorodibenzofuran Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers®	Statistical Plots of Octachlorodibenzofuran Concentrations	Figure 6

ng/kg - nanogram per kilogram

Figure 7a: Line Plot of Heptachlorinated Dibenzo-p-dioxins, (Total) Concentrations

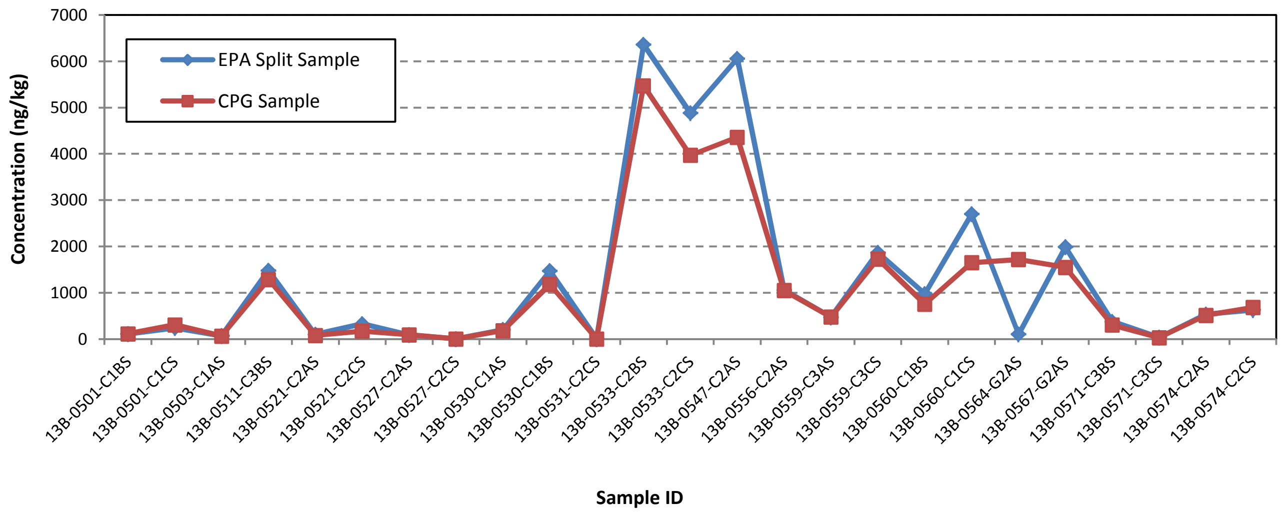


Figure 7b: Bivariate Scatter Plot of Heptachlorinated Dibenzo-p-dioxins, (Total) Concentrations

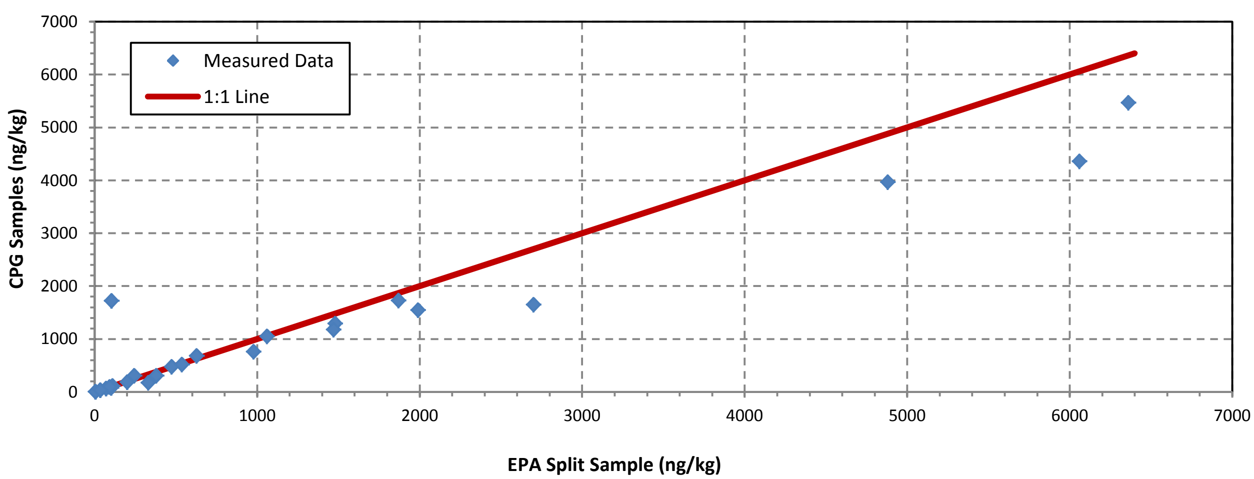
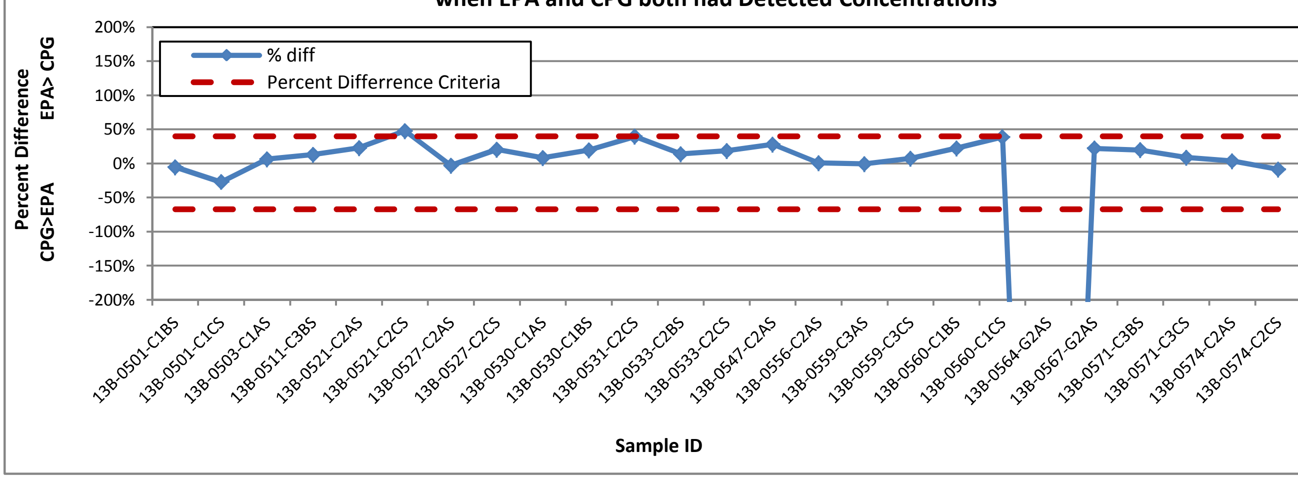


Figure 7c: Line Plot of Heptachlorinated Dibenzo-p-dioxins, (Total) Percent Differences when EPA and CPG both had Detected Concentrations



	Statistical Plots of Heptachlorinated Dibenzo-p-dioxins, (Total) Concentrations	Figure 7

ng/kg - nanogram per kilogram

Figure 8a: Line Plot of Tetrachlorinated Dibenzo-p-dioxins, (Total) Concentrations

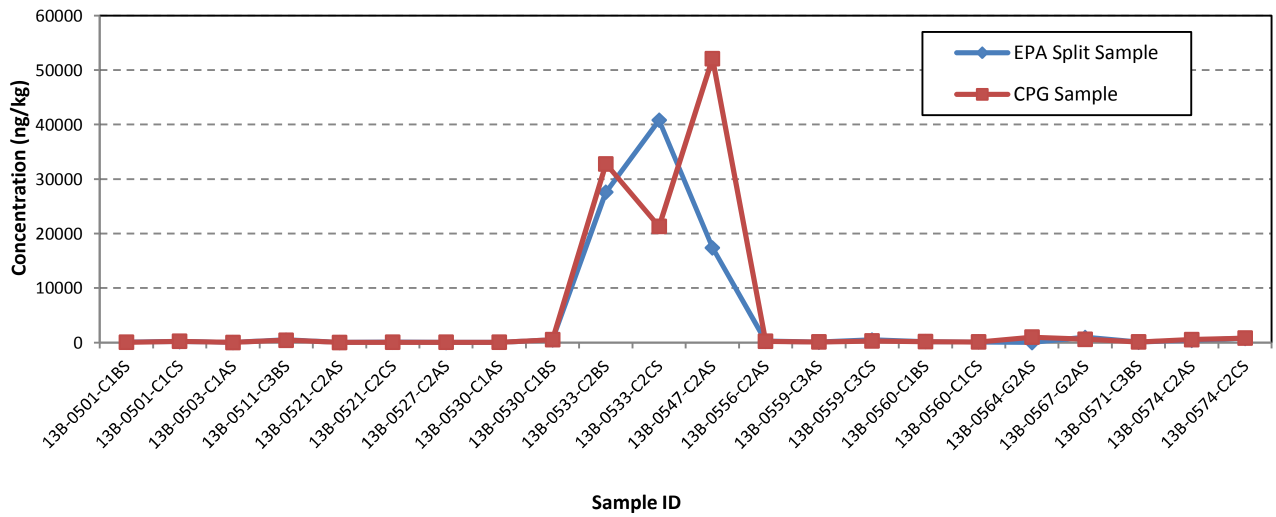


Figure 8b: Bivariate Scatter Plot of Tetrachlorinated Dibenzo-p-dioxins, (Total) Concentrations

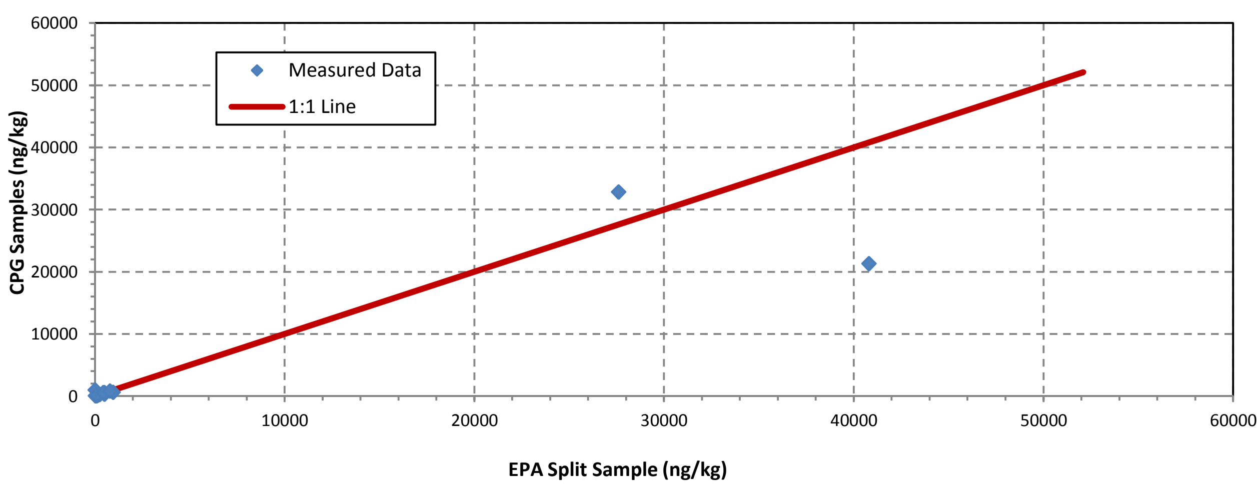
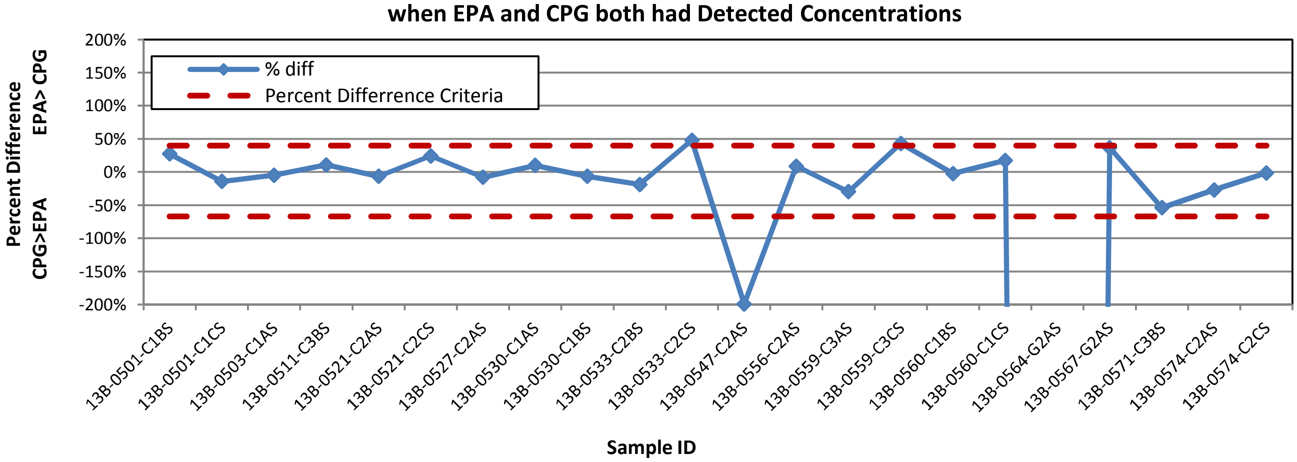
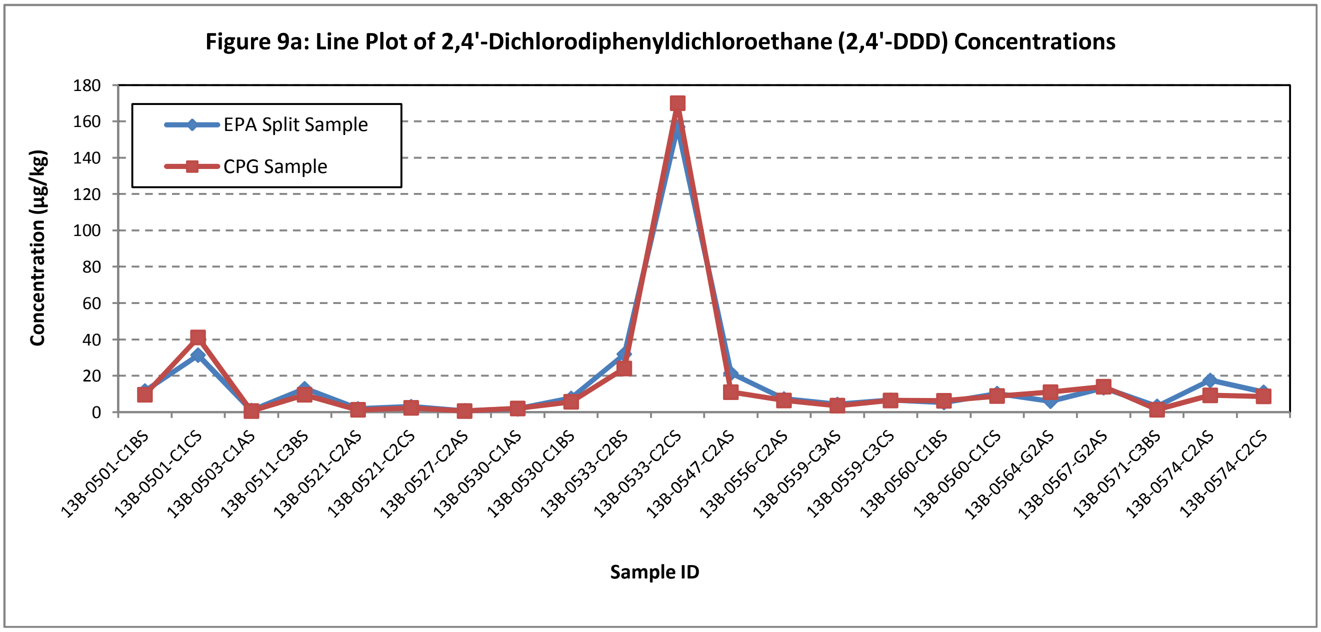


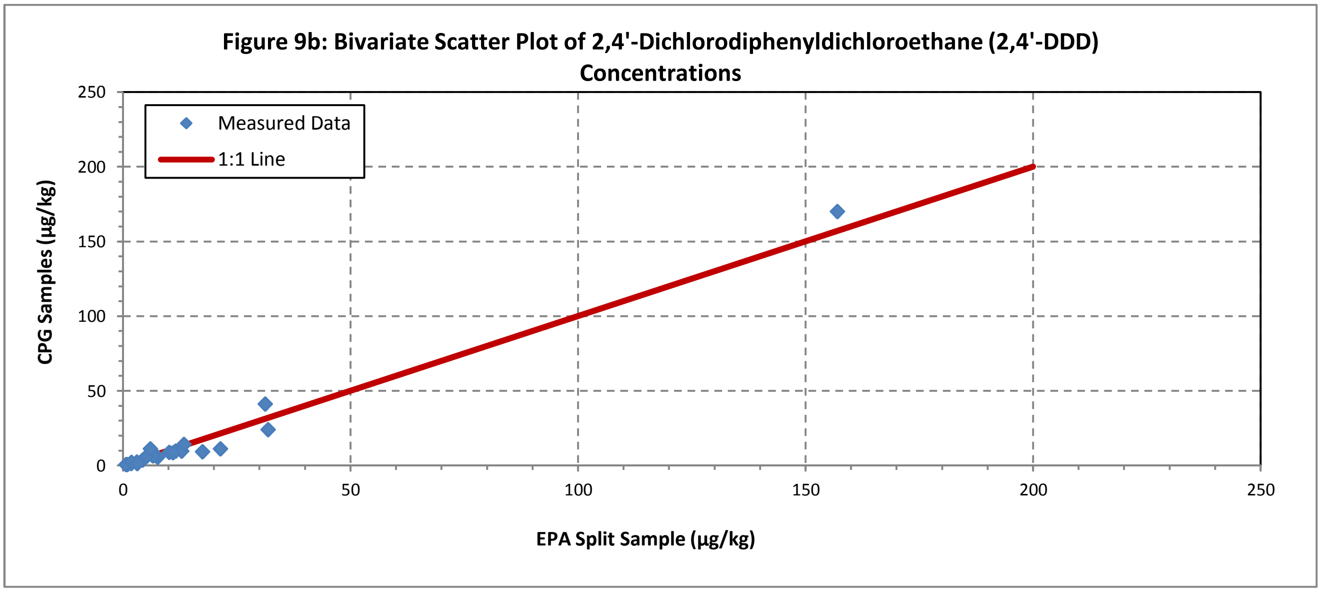
Figure 8c: Line Plot of Tetrachlorinated Dibenzo-p-dioxins, (Total) Percent Differences when EPA and CPG both had Detected Concentrations

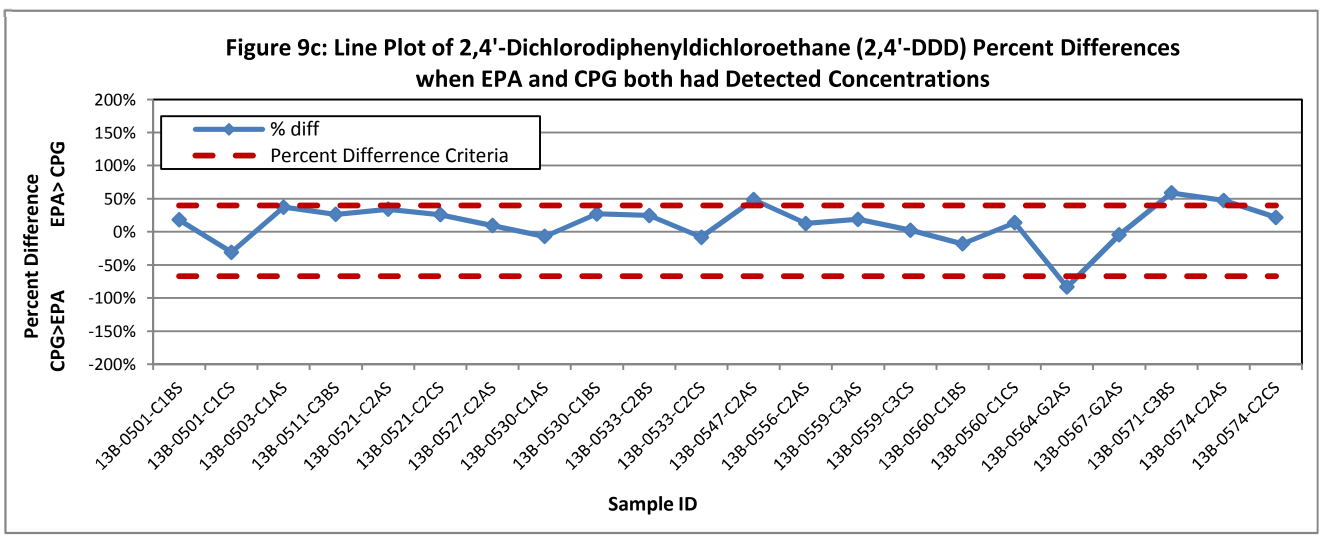


US Army Corps of Engineers	Statistical Plots of Tetrachlorinated Dibenzo-p-dioxins, (Total) Concentrations	Figure 8

ng/kg - nanogram per kilogram

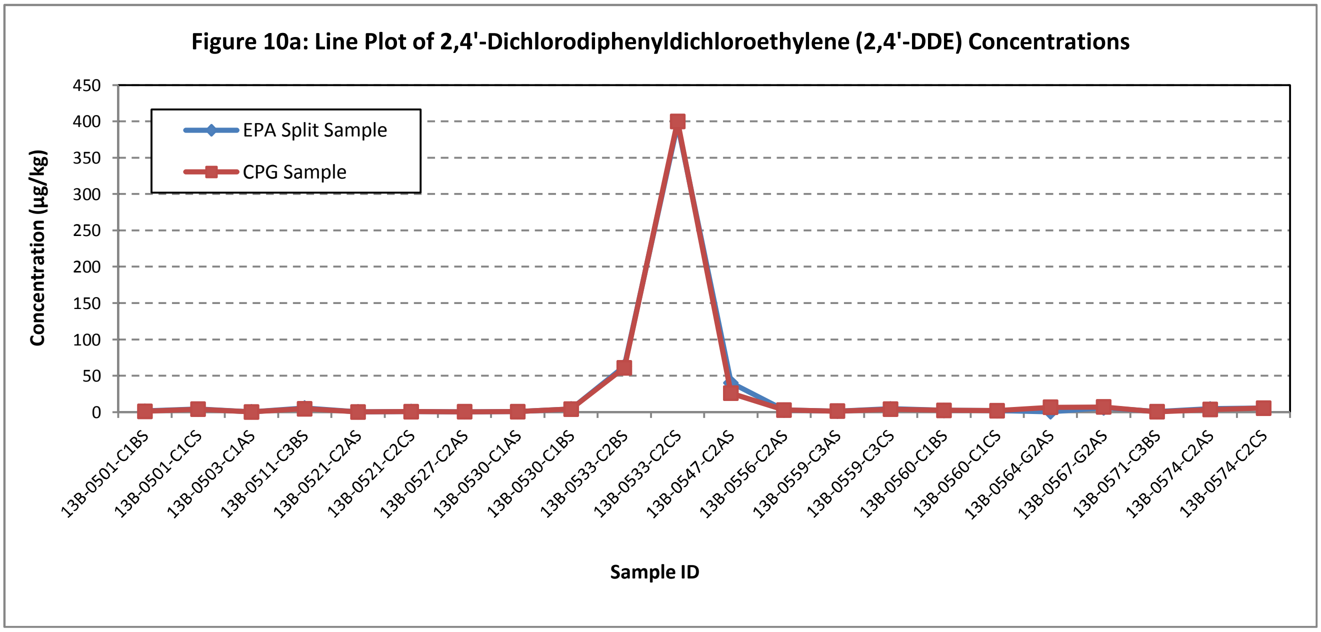


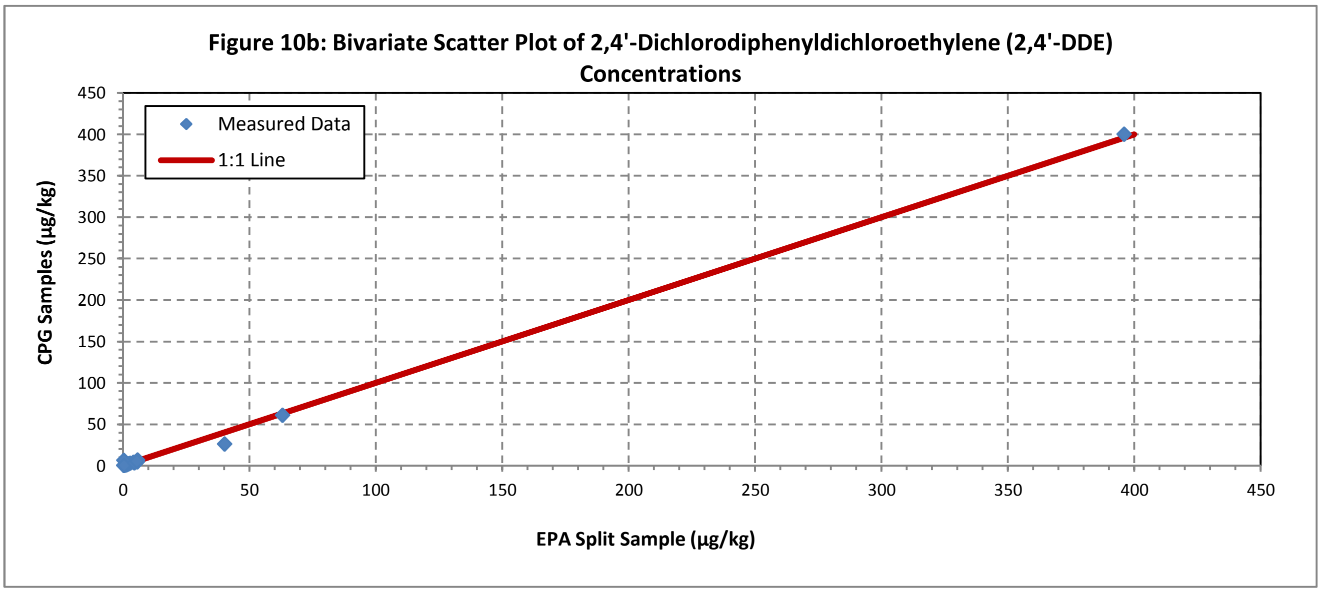


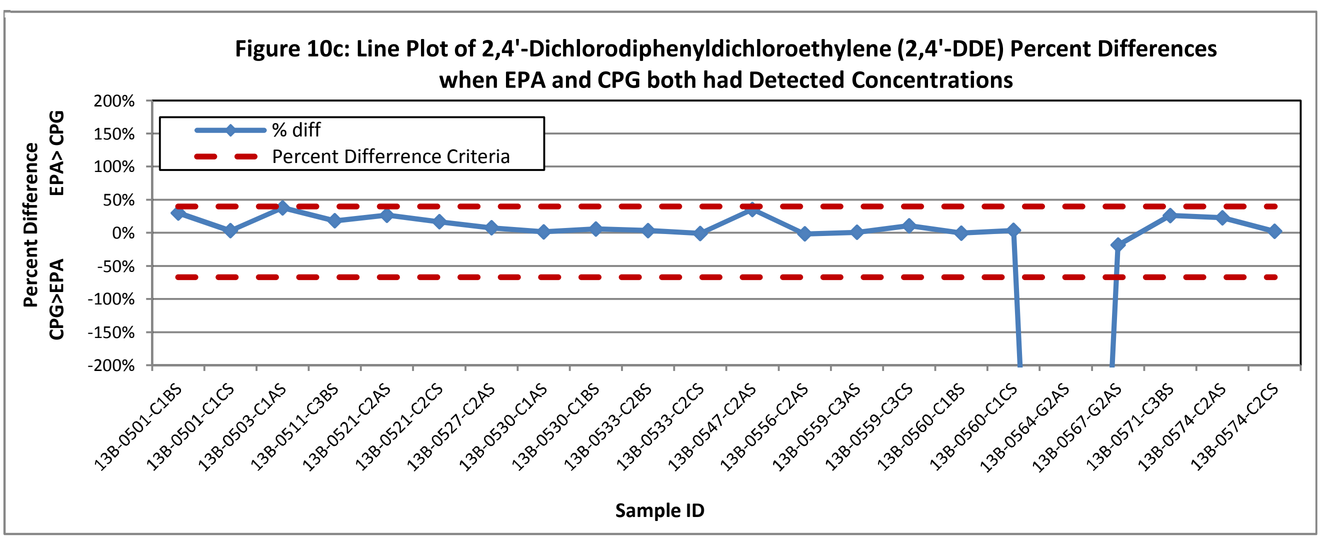


US Army Corps of Engineers	Statistical Plots of 2,4'-Dichlorodiphenyldichloroethane (2,4'-DDD) Concentrations	Figure 9

µg/kg - microgram per kilogram







US Army Corps of Engineers®

Statistical Plots of 2,4'-Dichlorodiphenyldichloroethylene (2,4'-DDE) Concentrations

Figure 10

µg/kg - microgram per kilogram

Figure 11a: Line Plot of 2,4'-Dichlorodiphenyltrichloroethane (2,4'-DDT) Concentrations

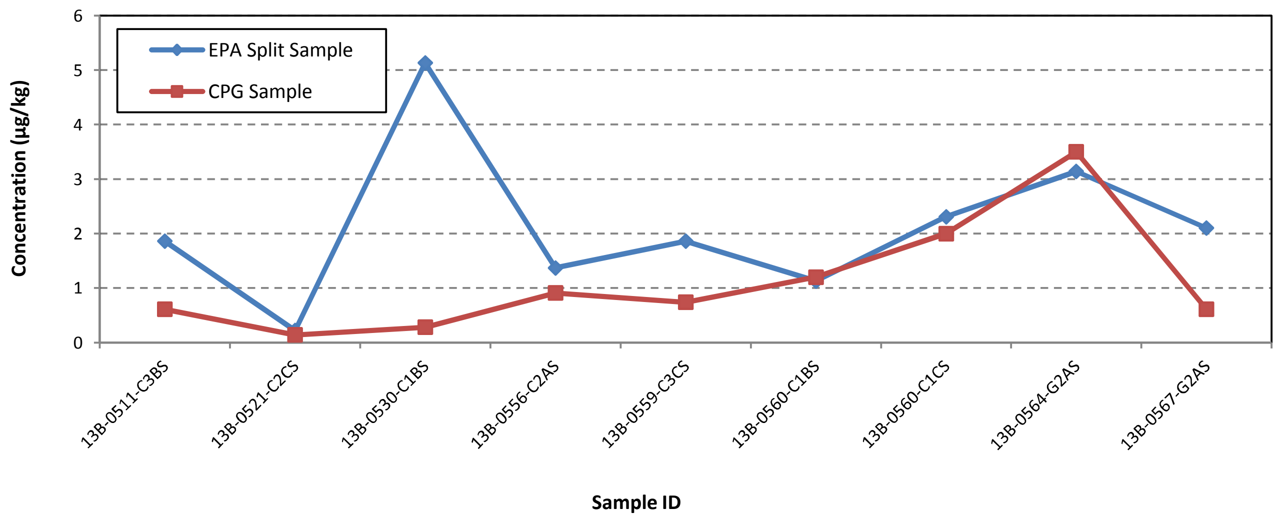


Figure 11b: Bivariate Scatter Plot of 2,4'-Dichlorodiphenyltrichloroethane (2,4'-DDT) Concentrations

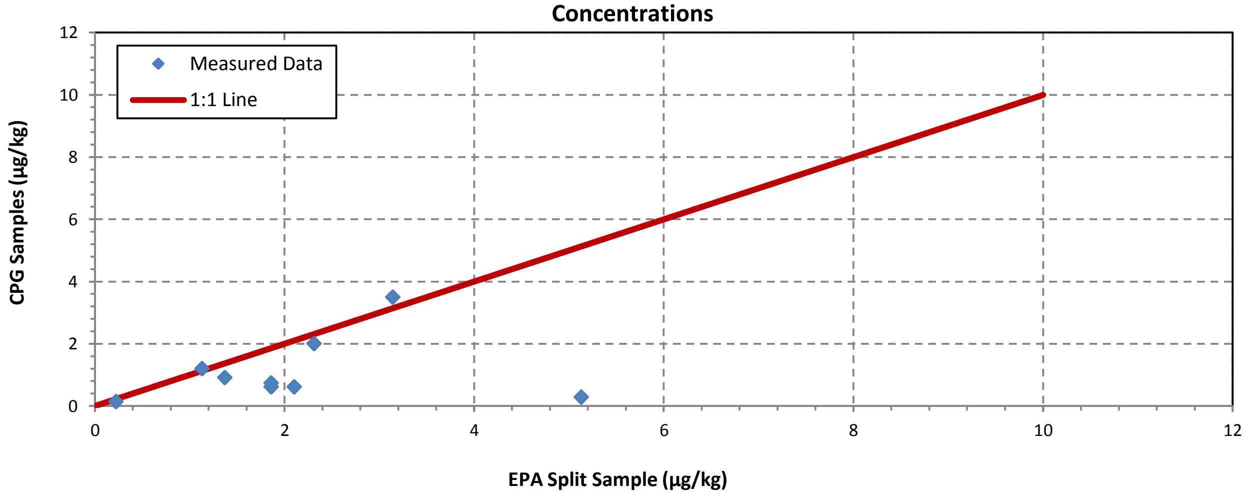
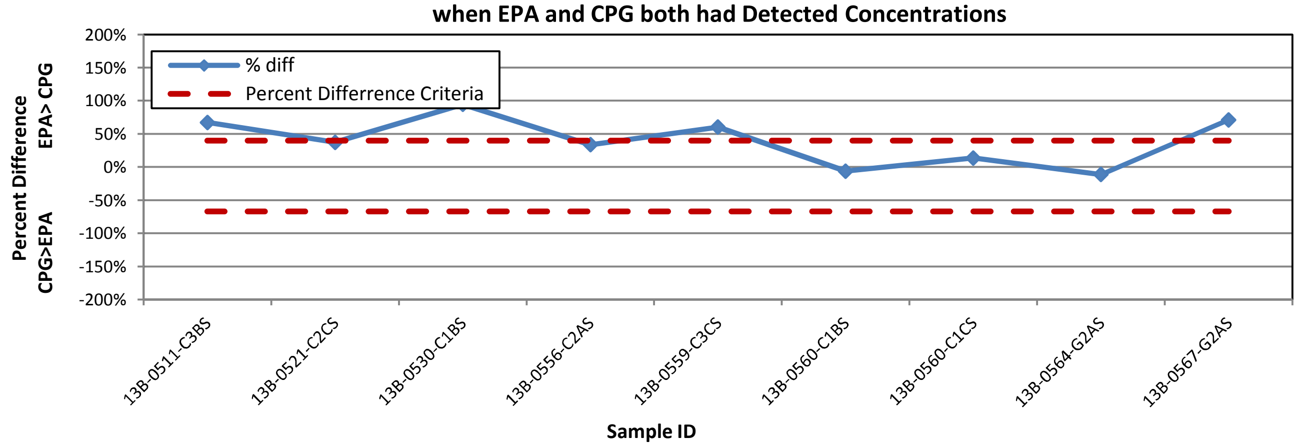


Figure 11c: Line Plot of 2,4'-Dichlorodiphenyltrichloroethane (2,4'-DDT) Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of 2,4'-Dichlorodiphenyltrichloroethane (2,4'-DDT) Concentrations	Figure 11

µg/kg - microgram per kilogram

Figure 12a: Line Plot of 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD) Concentrations

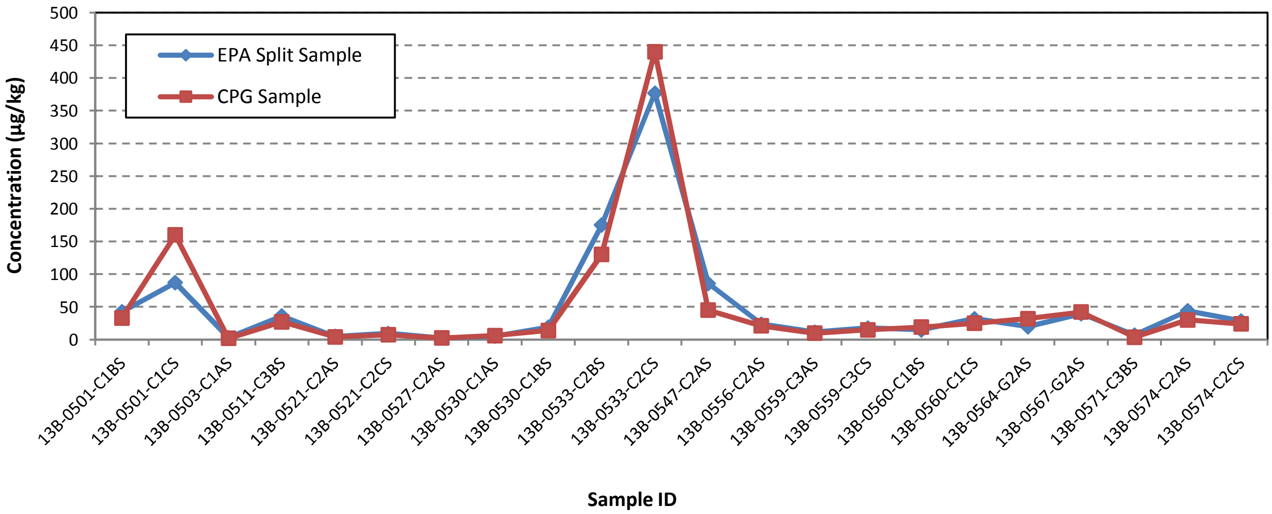


Figure 12b: Bivariate Scatter Plot of 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD) Concentrations

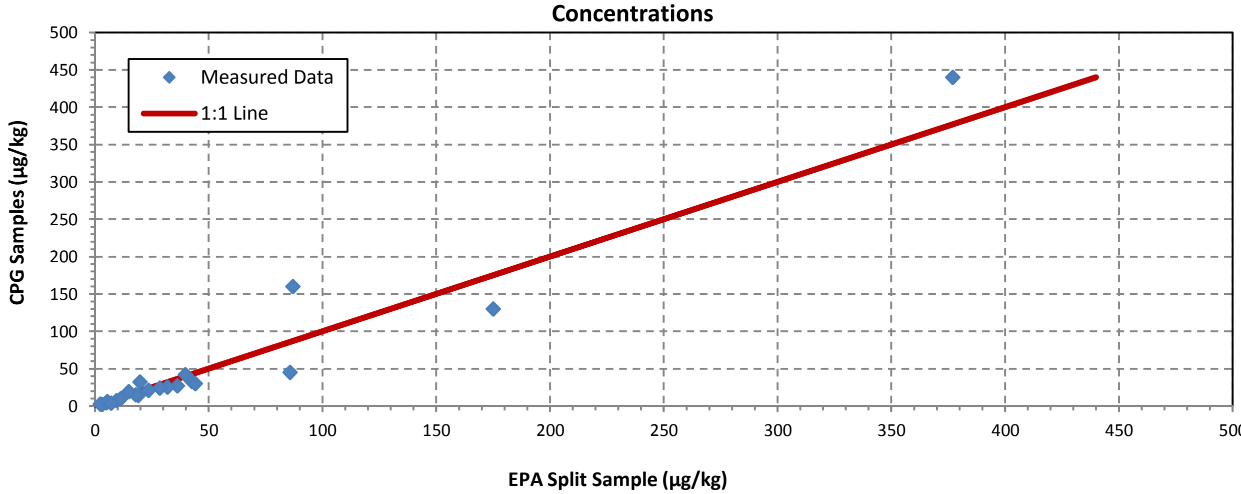
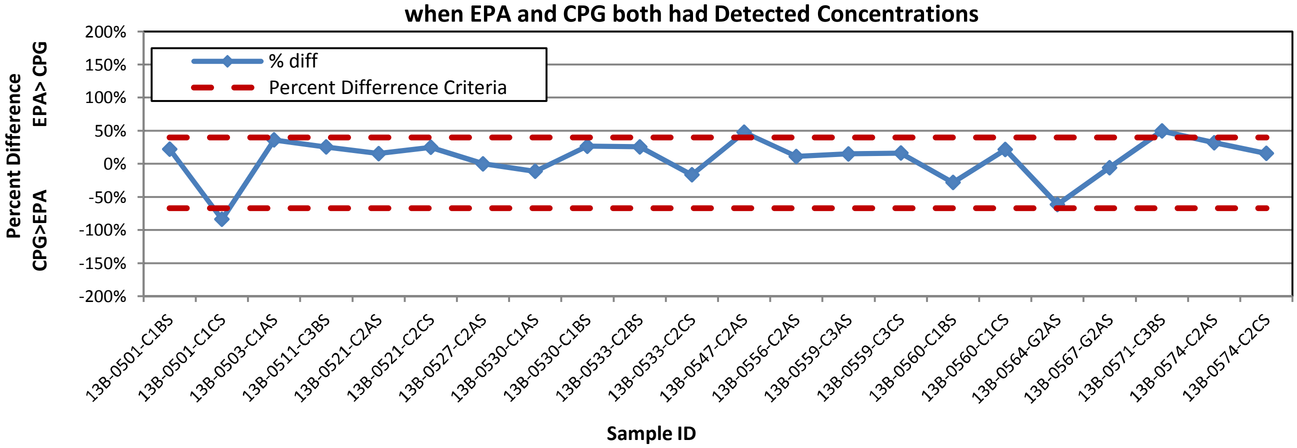


Figure 12c: Line Plot of 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD) Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers®	**Statistical Plots of 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD) Concentrations**	**Figure 12**

µg/kg - microgram per kilogram

Figure 13a: Line Plot of 4,4'-Dichlorodiphenyldichloroethylene (4,4'-DDE) Concentrations

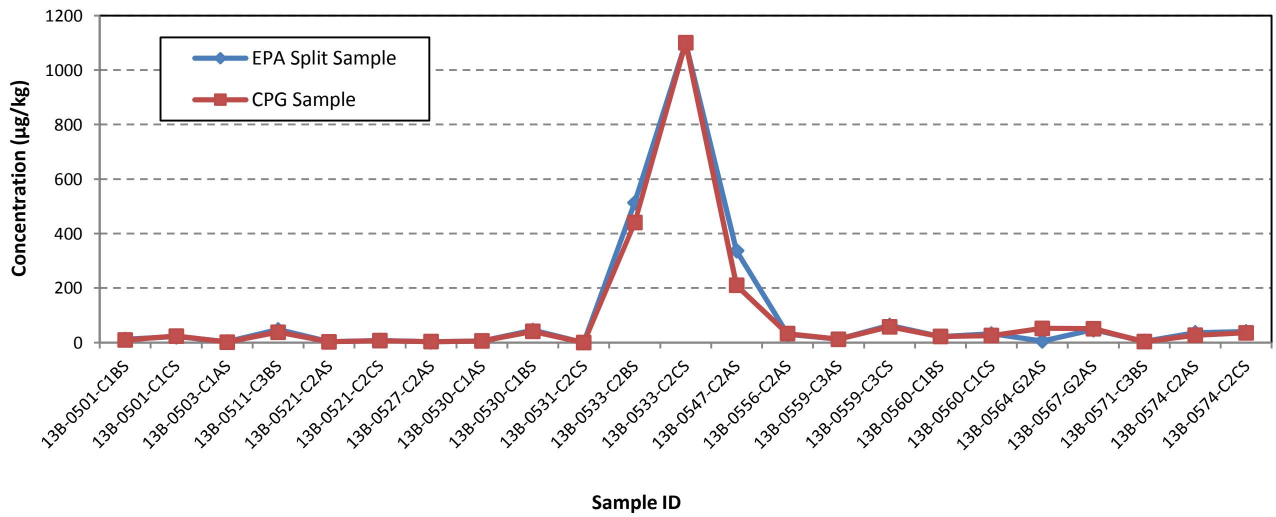


Figure 13b: Bivariate Scatter Plot of 4,4'-Dichlorodiphenyldichloroethylene (4,4'-DDE) Concentrations

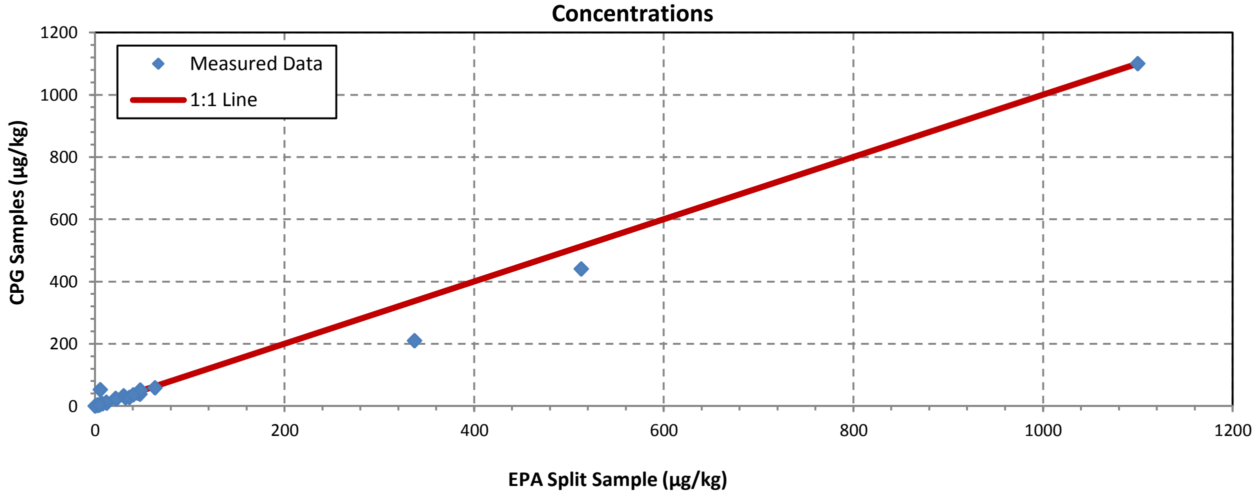
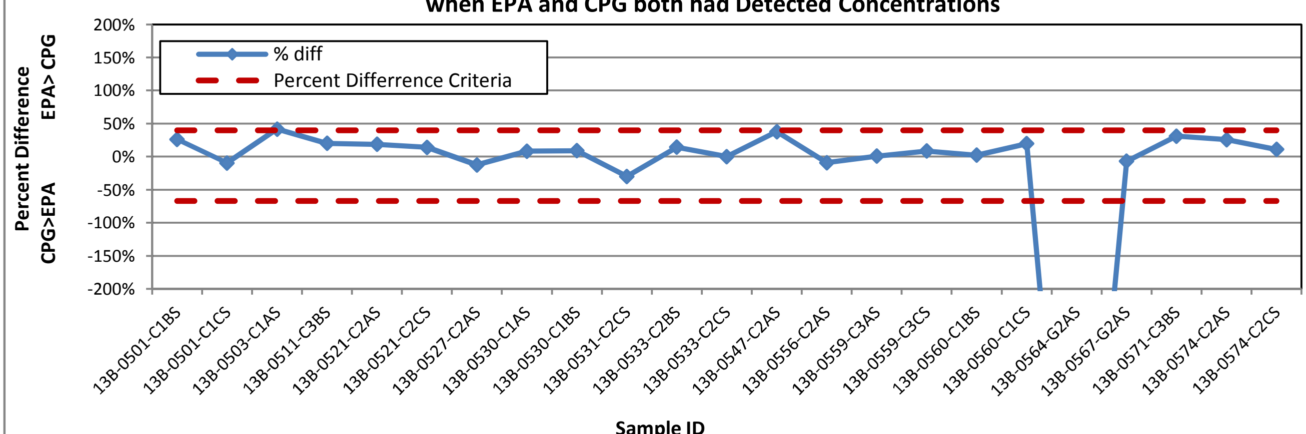


Figure 13c: Line Plot of 4,4'-Dichlorodiphenyldichloroethylene (4,4'-DDE) Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers®

Statistical Plots of 4,4'-Dichlorodiphenyldichloroethylene (4,4'-DDE) Concentrations

Figure 13

µg/kg - microgram per kilogram

Figure 14a: Line Plot of 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT) Concentrations

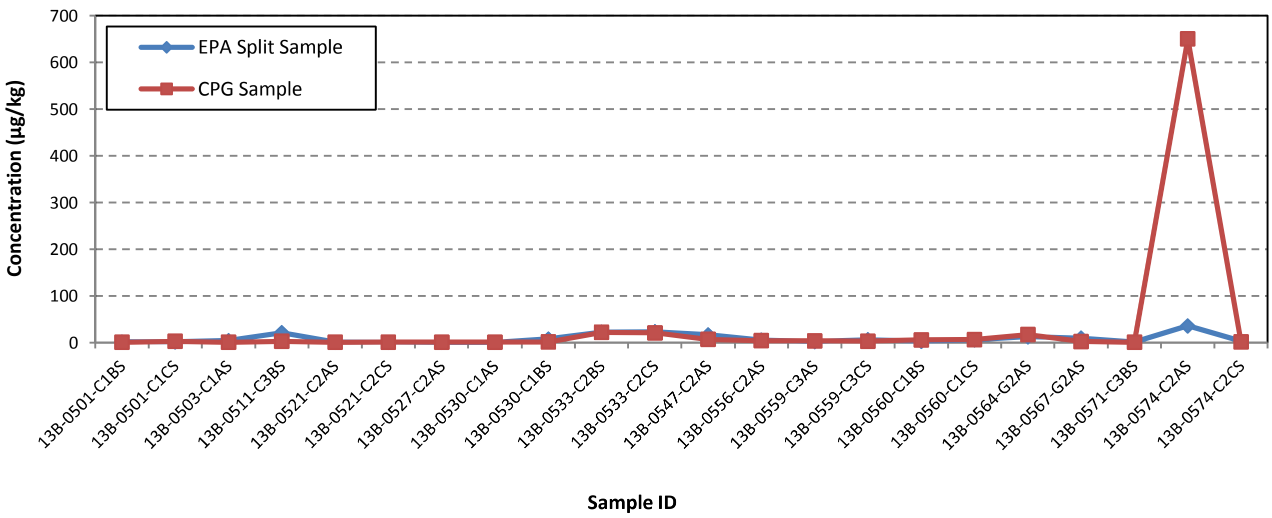


Figure 14b: Bivariate Scatter Plot of 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT) Concentrations

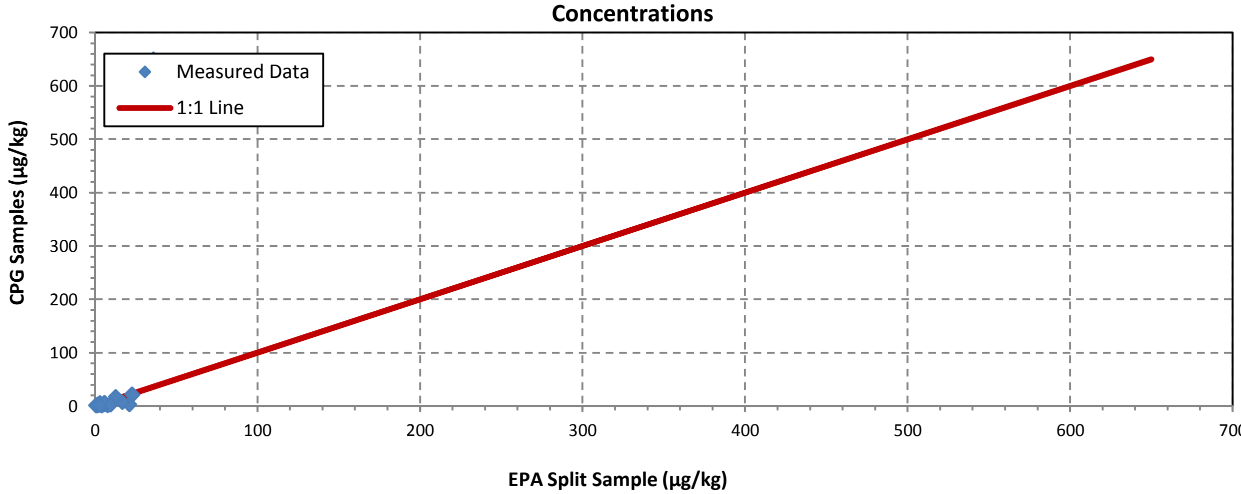
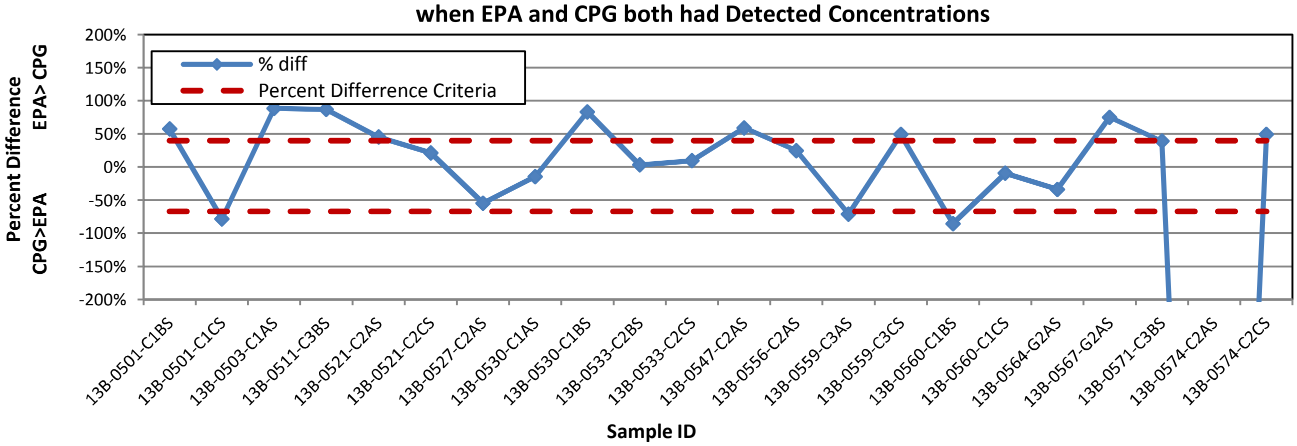


Figure 14c: Line Plot of 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT) Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers®	**Statistical Plots of 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT) Concentrations**	**Figure 14**

µg/kg - microgram per kilogram

Figure 15a: Line Plot of alpha-Chlordane Concentrations

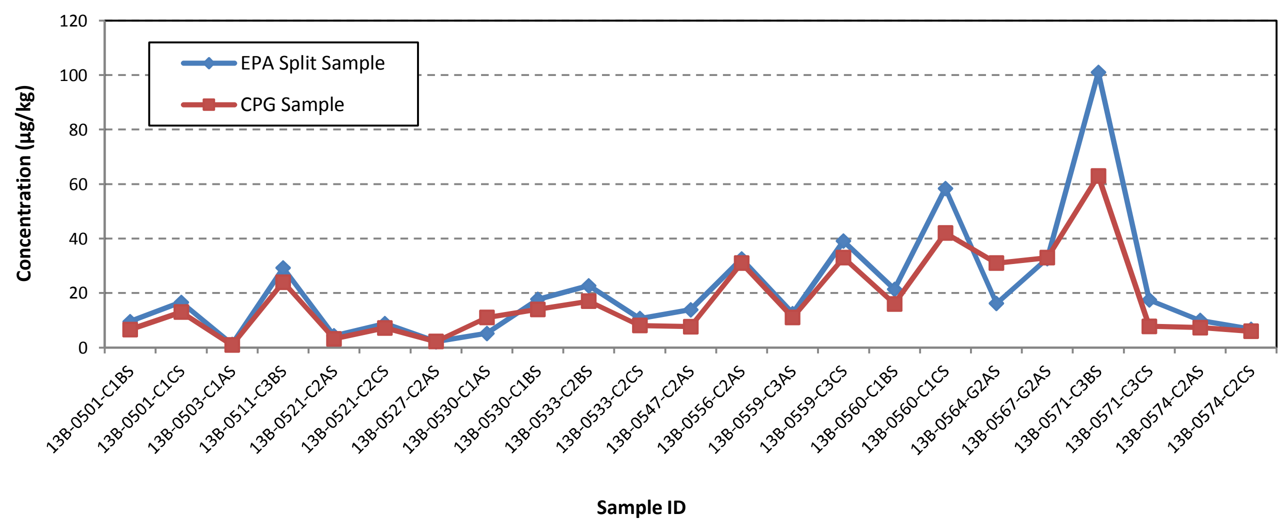


Figure 15b: Bivariate Scatter Plot of alpha-Chlordane Concentrations

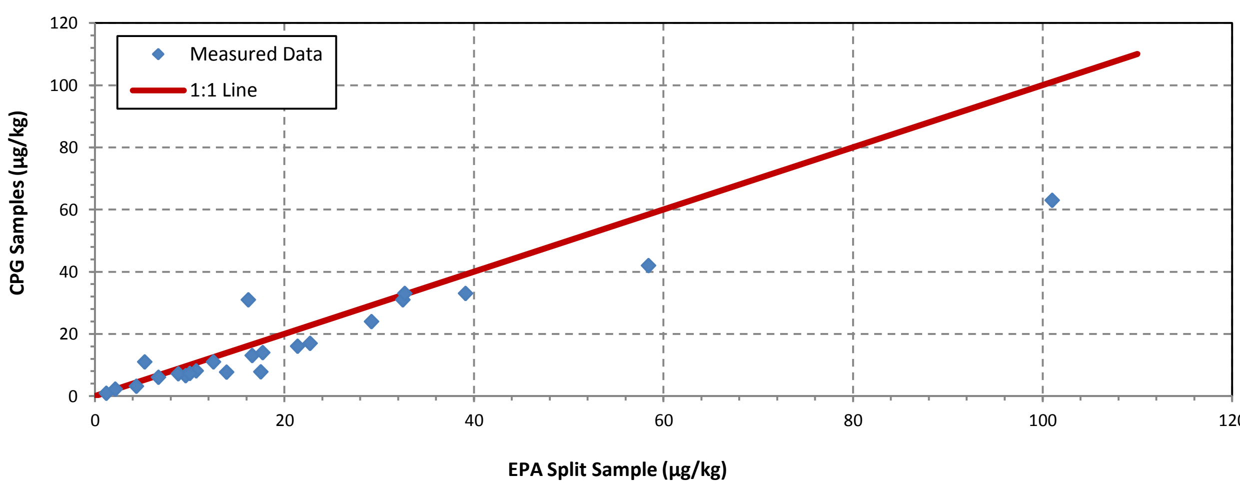
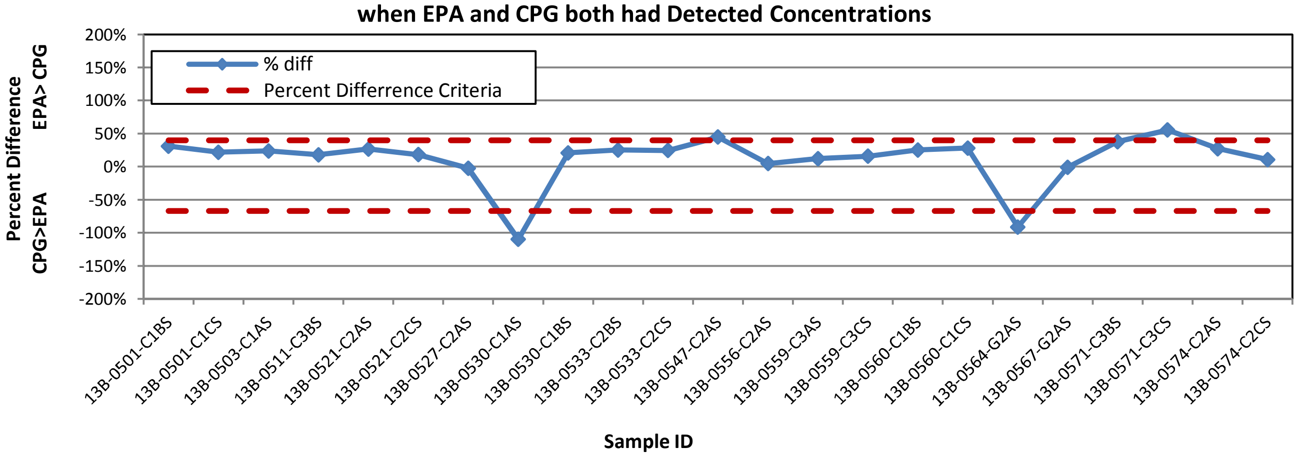
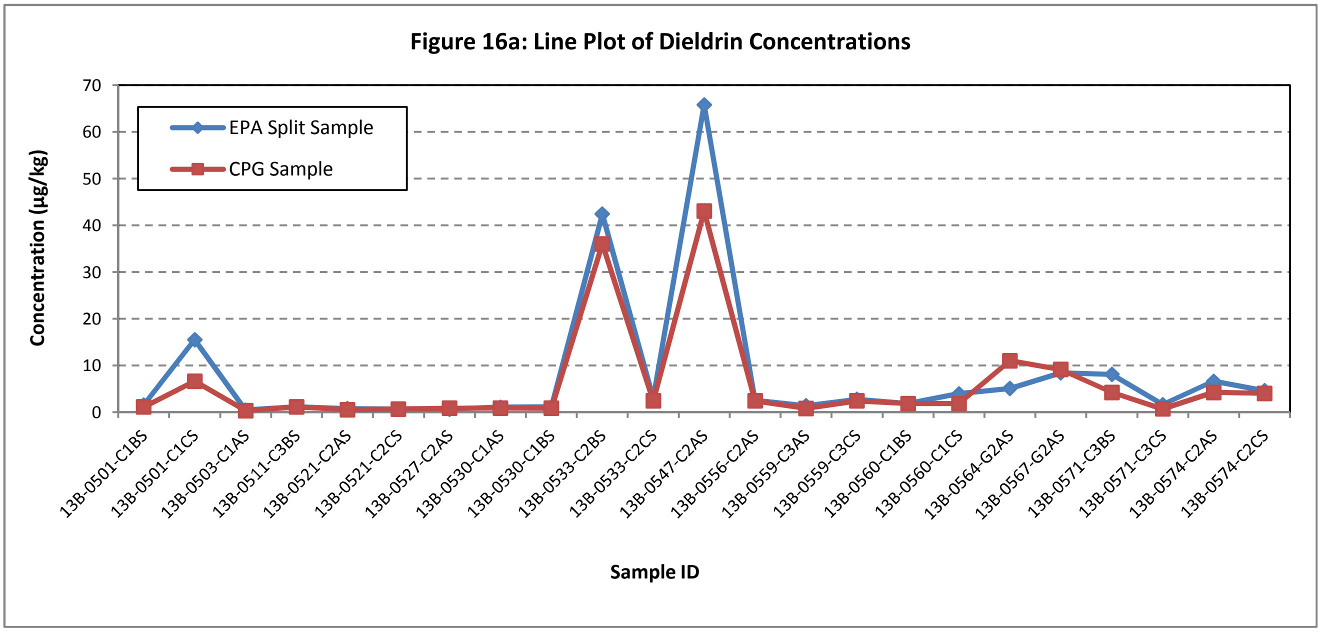


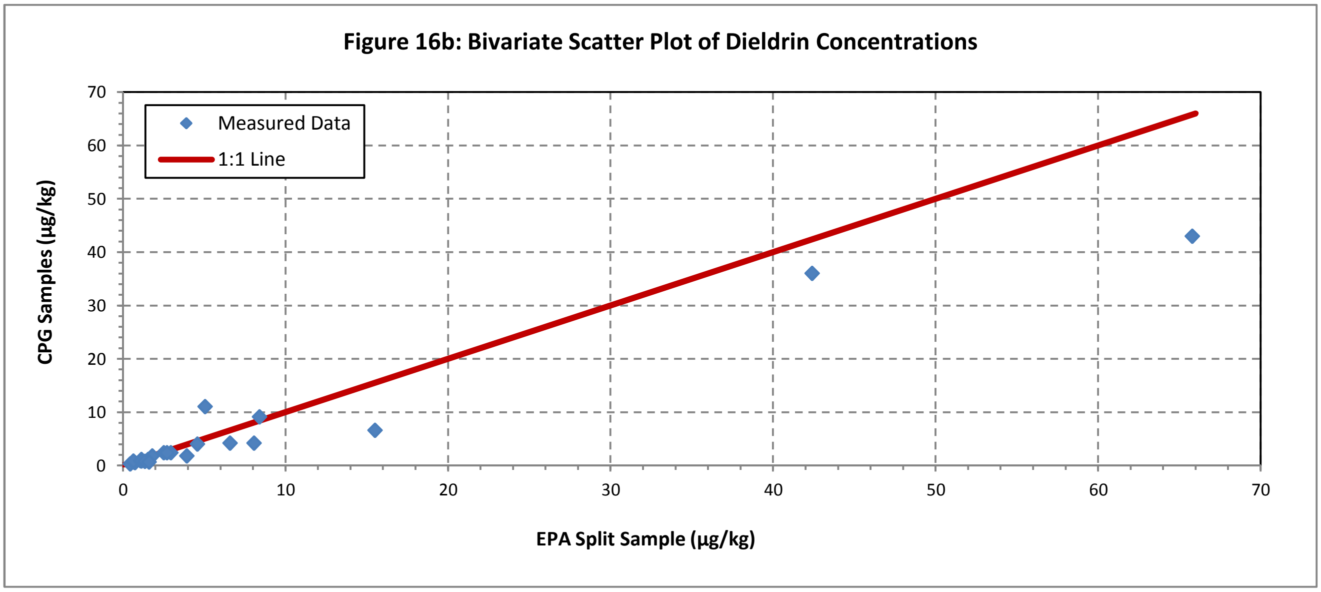
Figure 15c: Line Plot of alpha-Chlordane Percent Differences when EPA and CPG both had Detected Concentrations

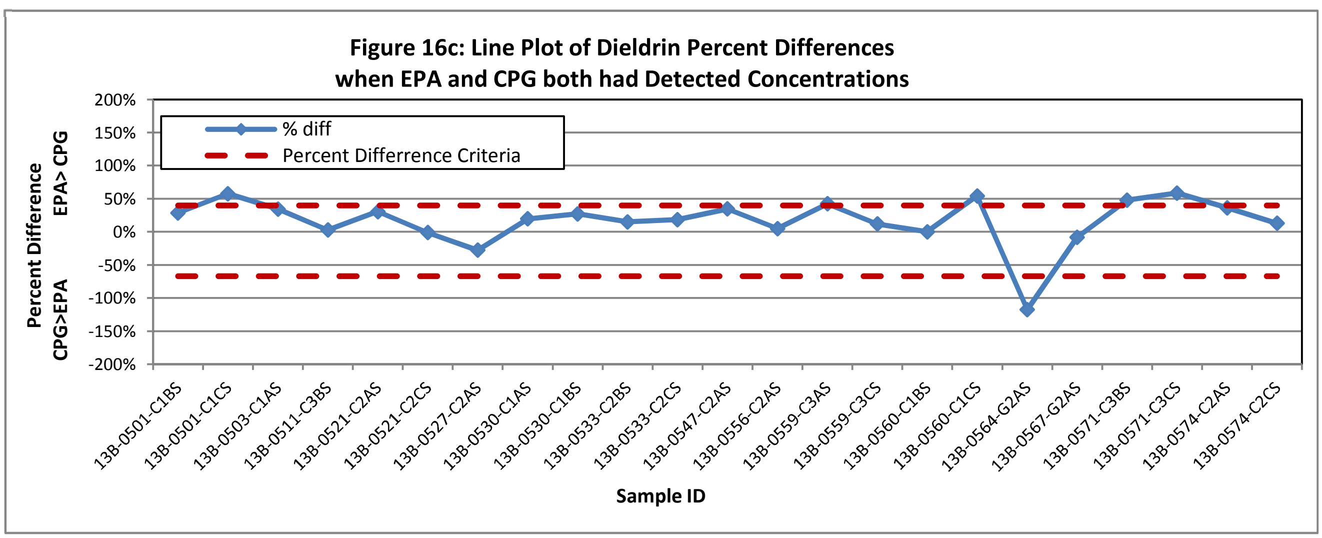


US Army Corps of Engineers	Statistical Plots of alpha-Chlordane Concentrations	Figure 15

µg/kg - microgram per kilogram

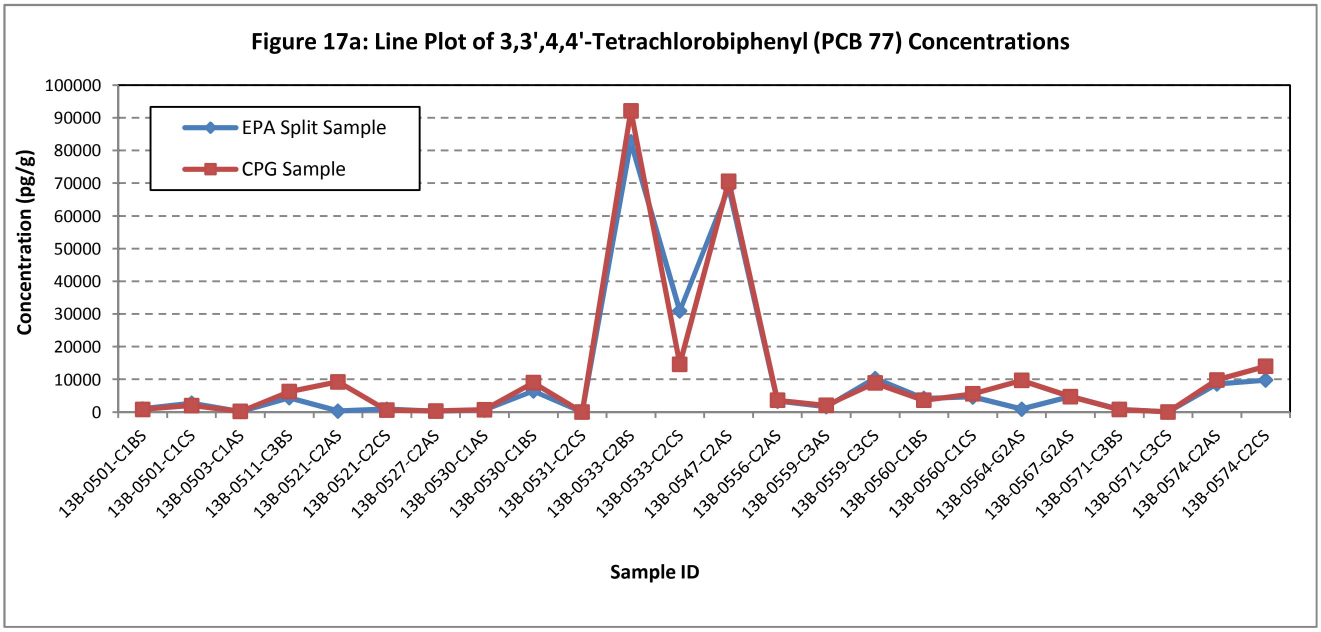


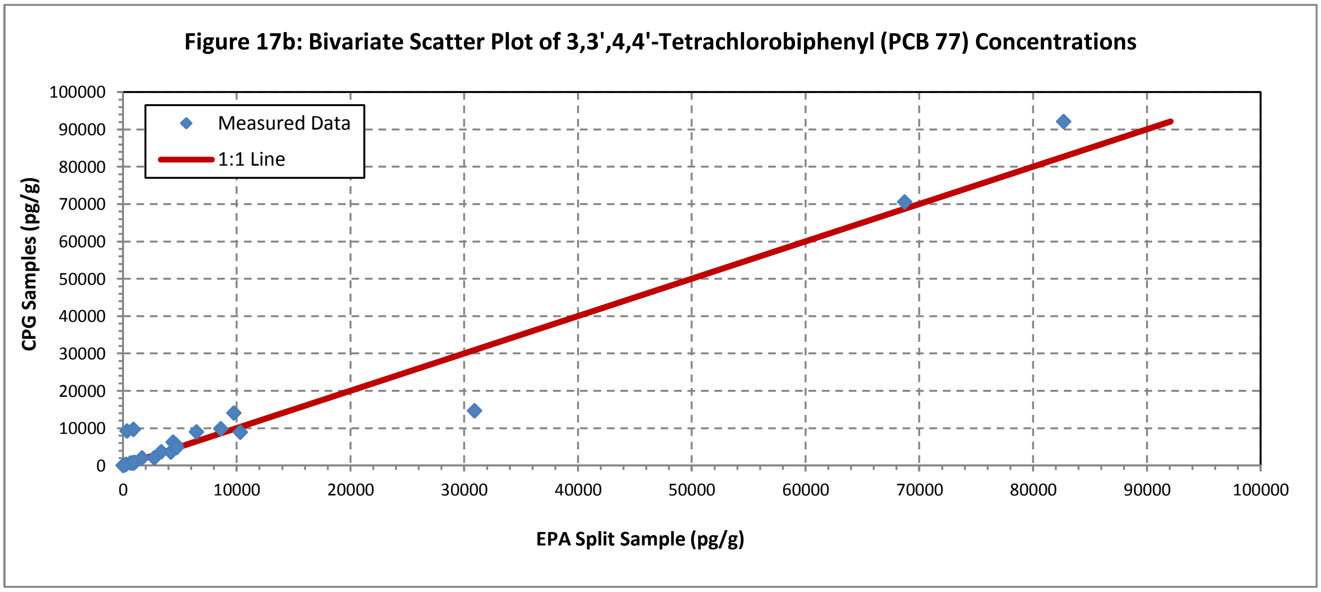


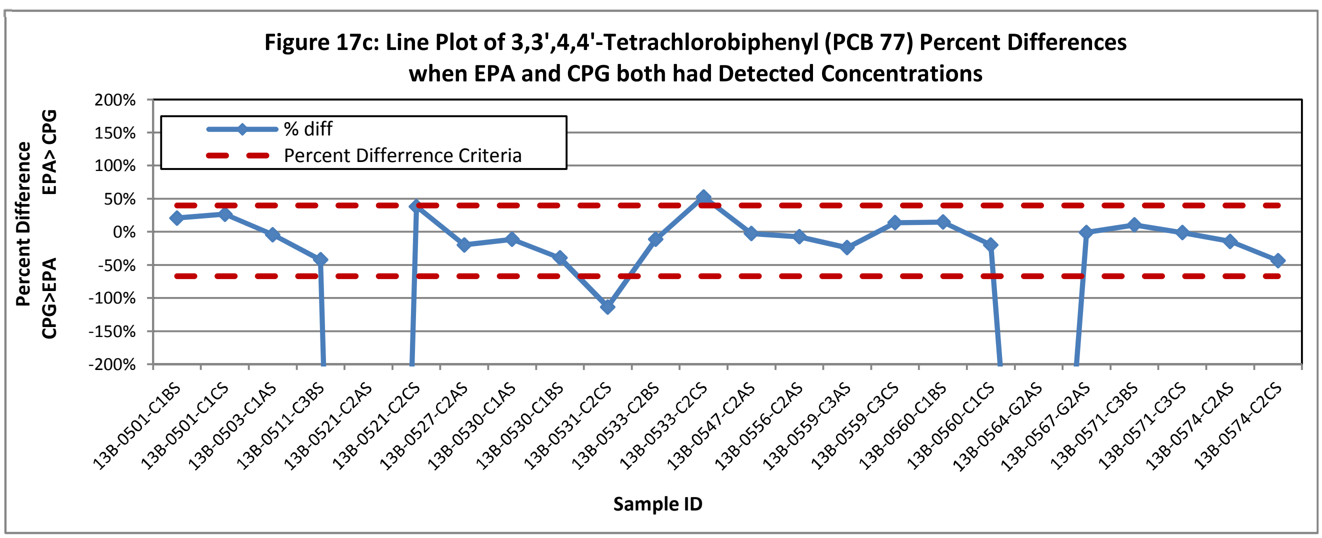


US Army Corps of Engineers®	**Statistical Plots of Dieldrin Concentrations**	**Figure 16**

µg/kg - microgram per kilogram





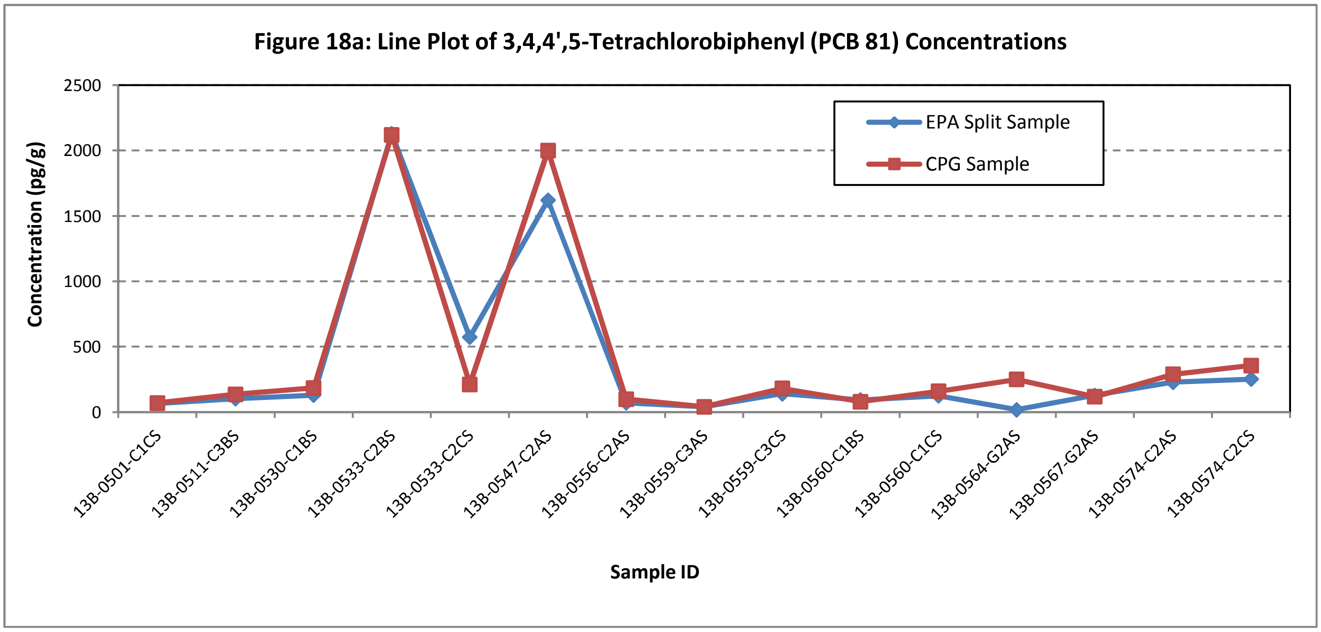


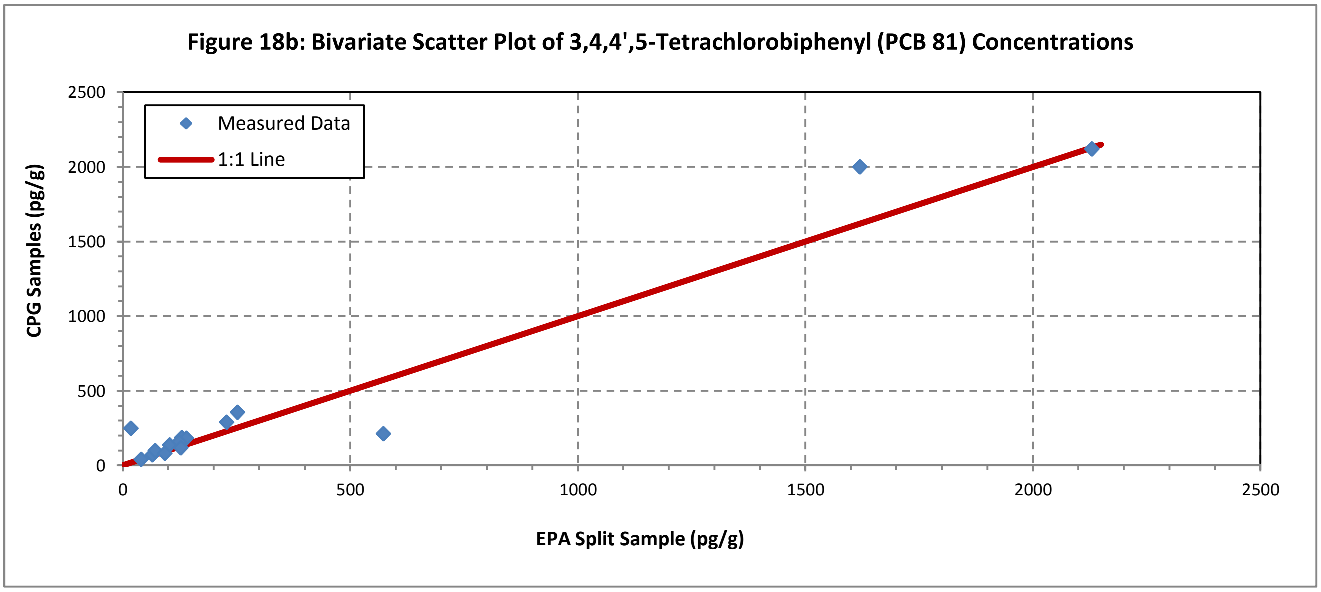
US Army Corps of Engineers

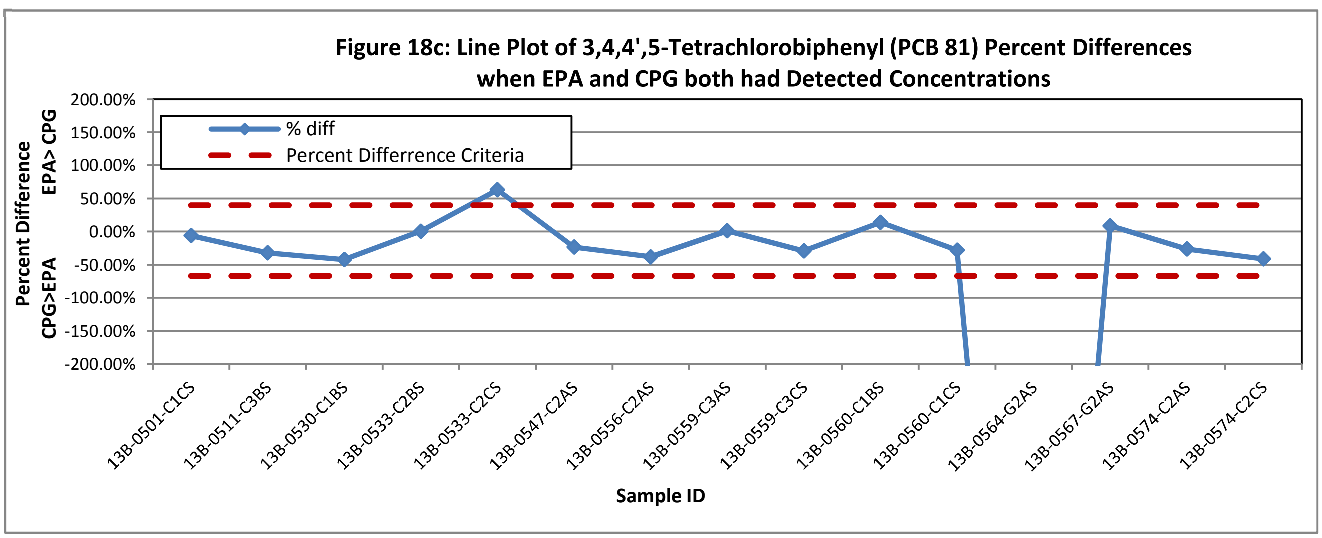
Statistical Plots of 3,3',4,4'-Tetrachlorobiphenyl (PCB 77) Concentrations

Figure 17

pg/g - picogram per gram

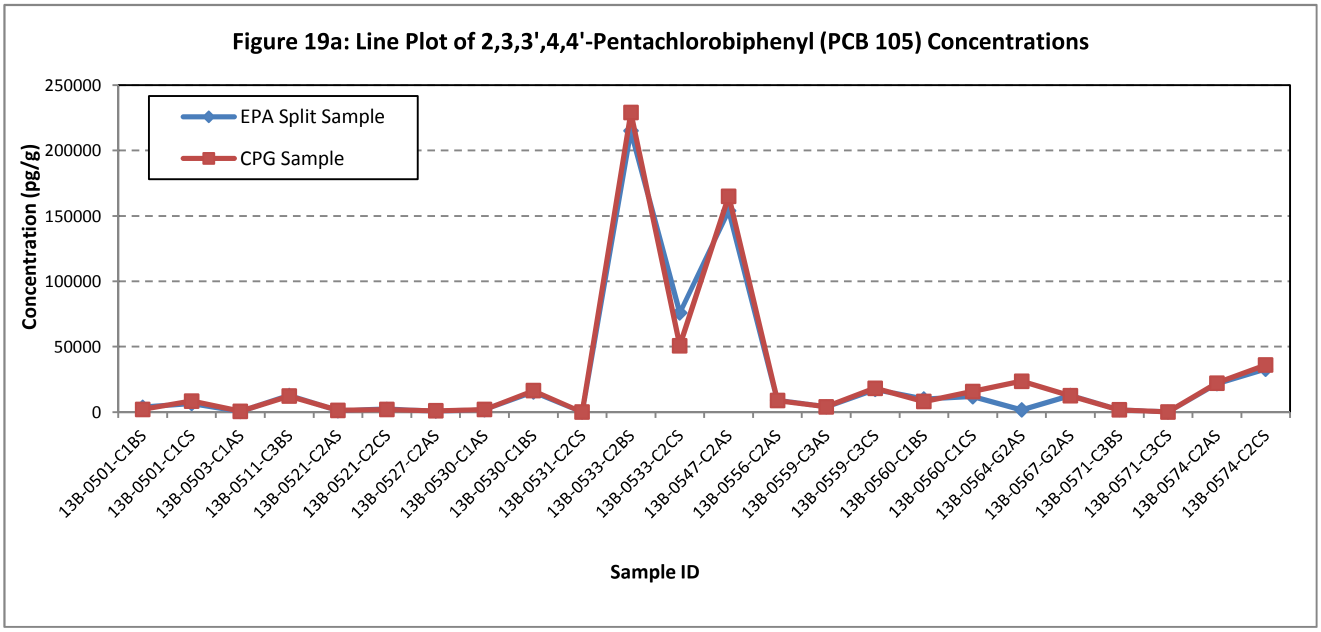


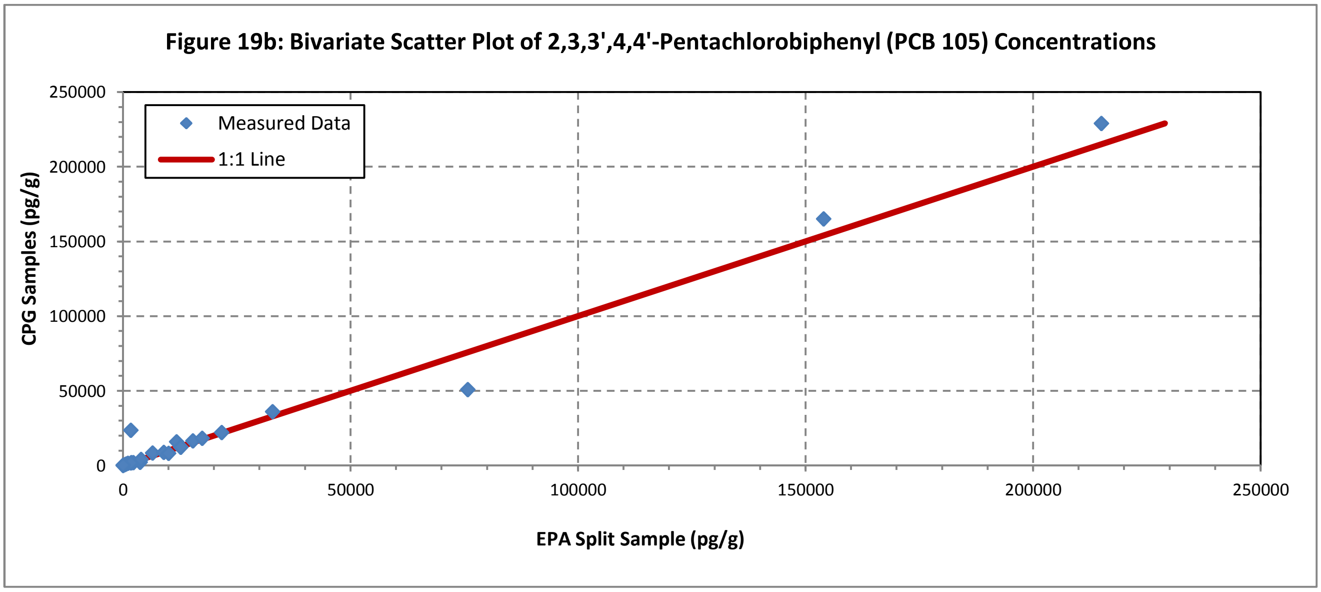


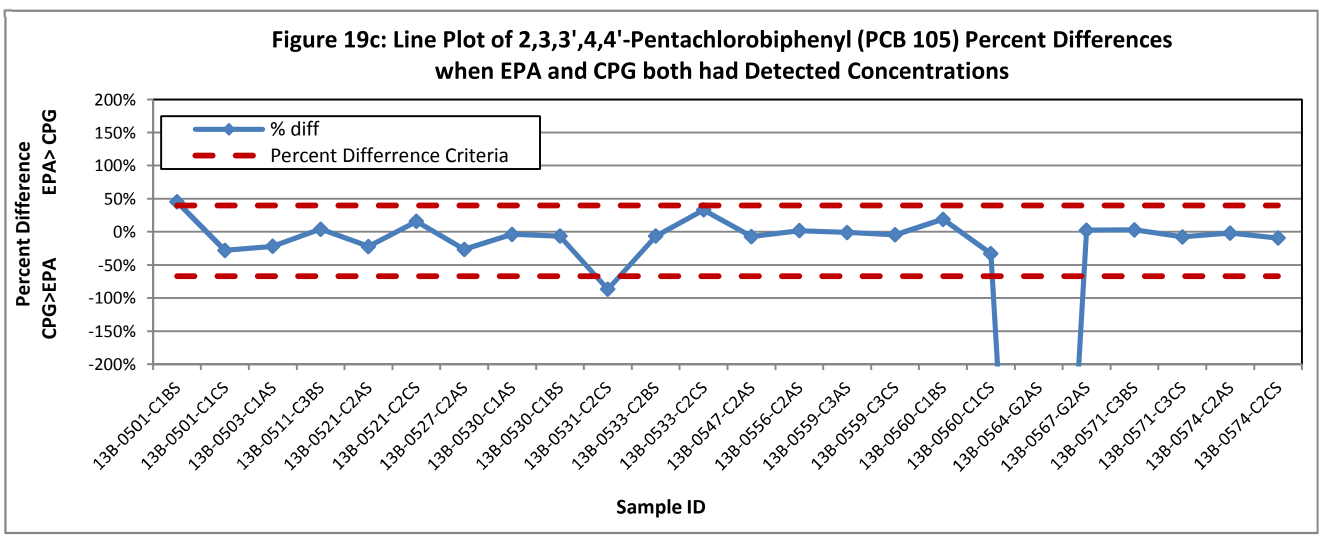


US Army Corps of Engineers	**Statistical Plots of 3,4,4',5-Tetrachlorobiphenyl (PCB 81) Concentrations**	**Figure 18**

pg/g - picogram per gram







US Army Corps of Engineers	Statistical Plots of 2,3,3',4,4'-Pentachlorobiphenyl (PCB 105) Concentrations	Figure 19

pg/g - picogram per gram

Figure 20a: Line Plot of 2,3,4,4',5-Pentachlorobiphenyl (PCB 114) Concentrations

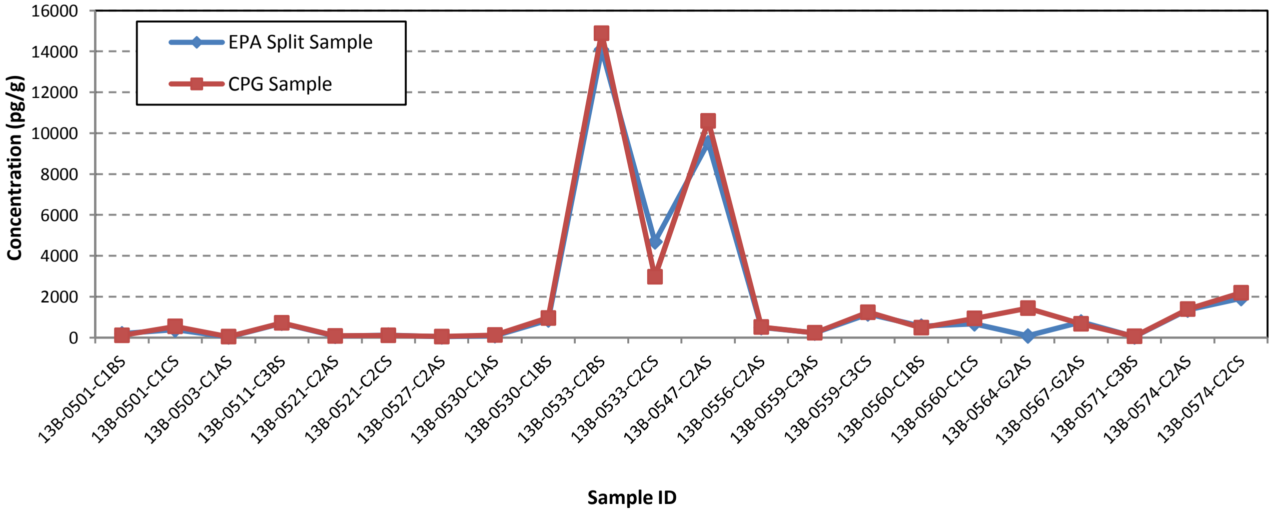


Figure 20b: Bivariate Scatter Plot of 2,3,4,4',5-Pentachlorobiphenyl (PCB 114) Concentrations

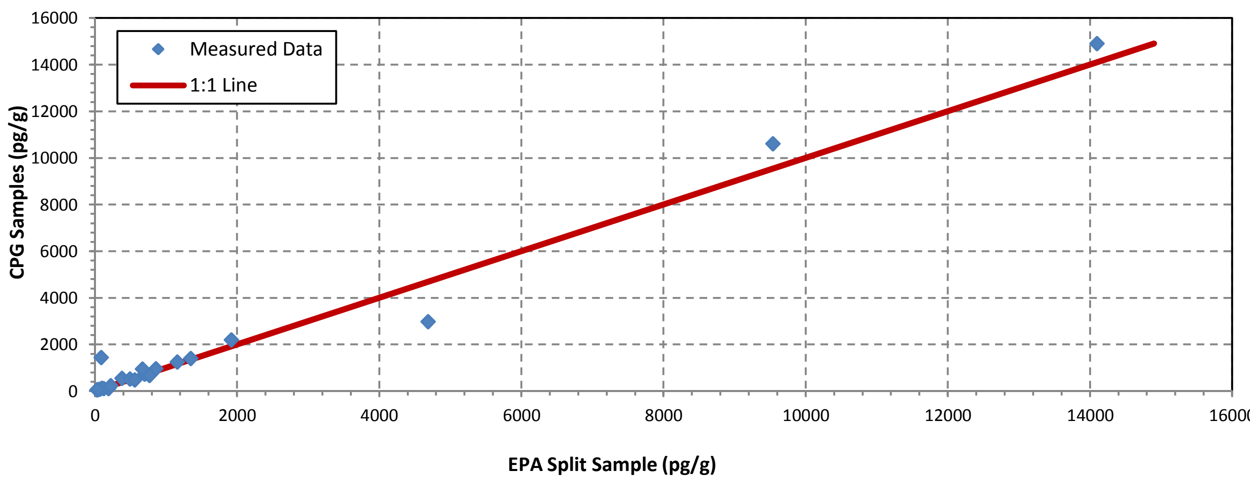
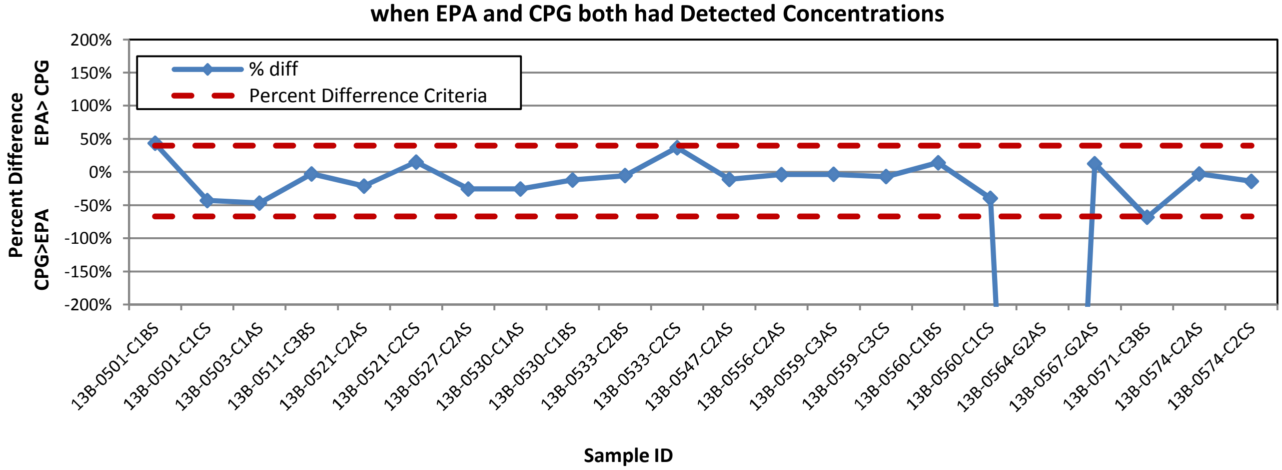


Figure 20c: Line Plot of 2,3,4,4',5-Pentachlorobiphenyl (PCB 114) Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	**Statistical Plots of 2,3,4,4',5-Pentachlorobiphenyl (PCB 114) Concentrations**	**Figure 20**

pg/g - picogram per gram

Figure 21a: Line Plot of 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) Concentrations

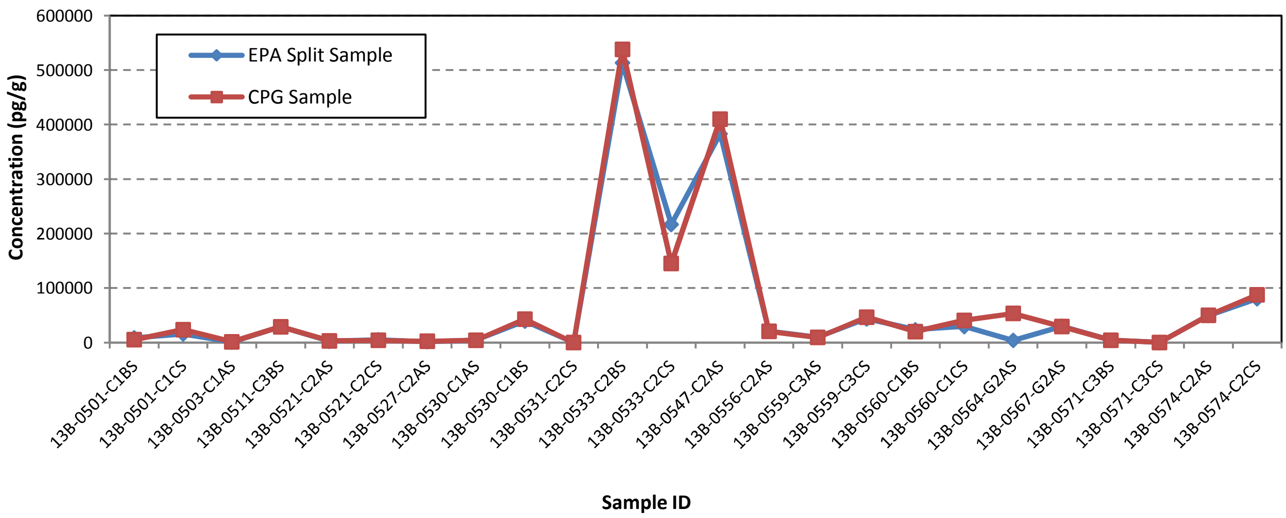


Figure 21b: Bivariate Scatter Plot of 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) Concentrations

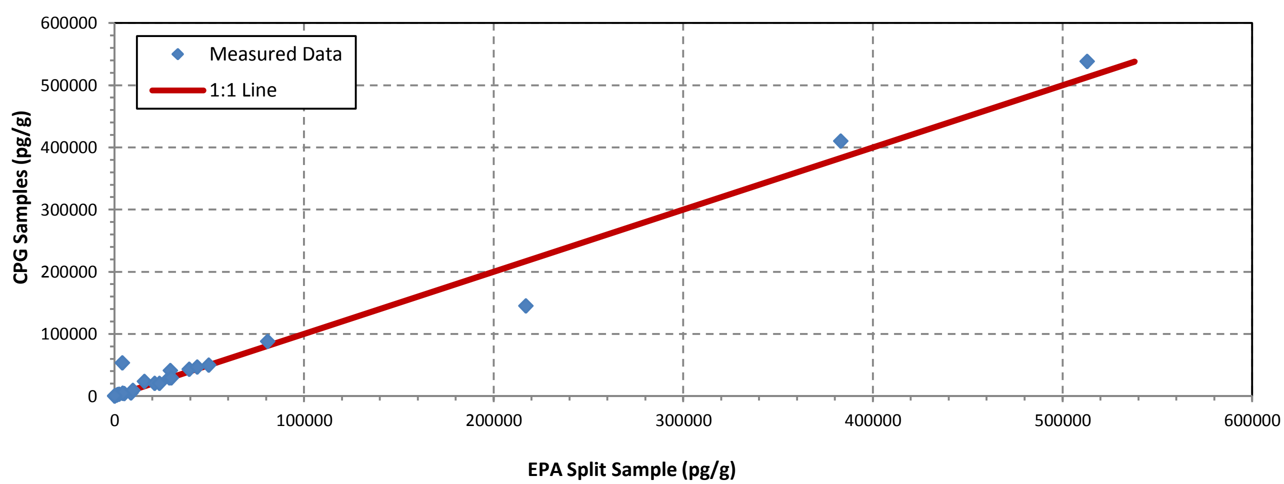
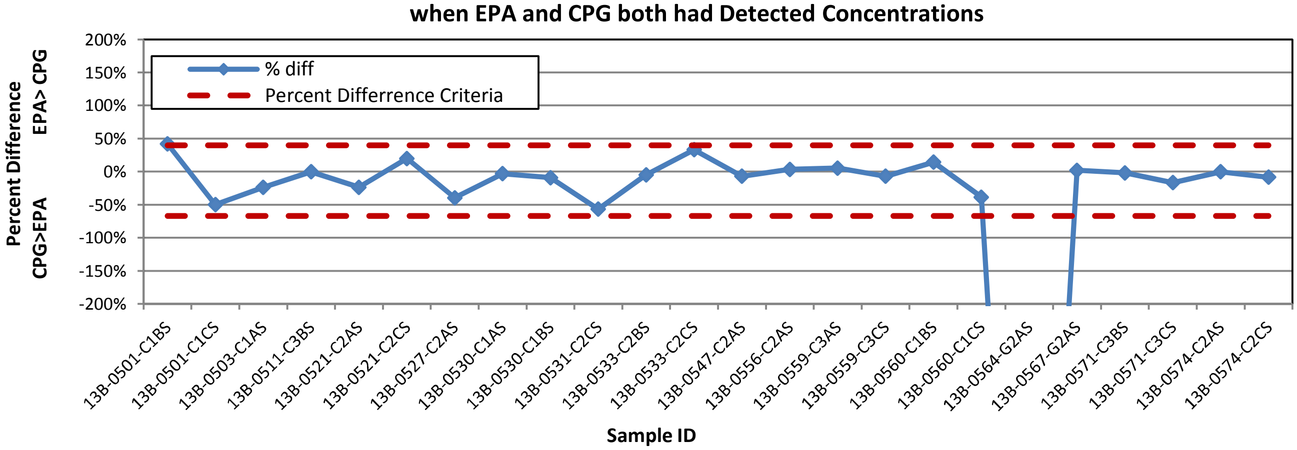
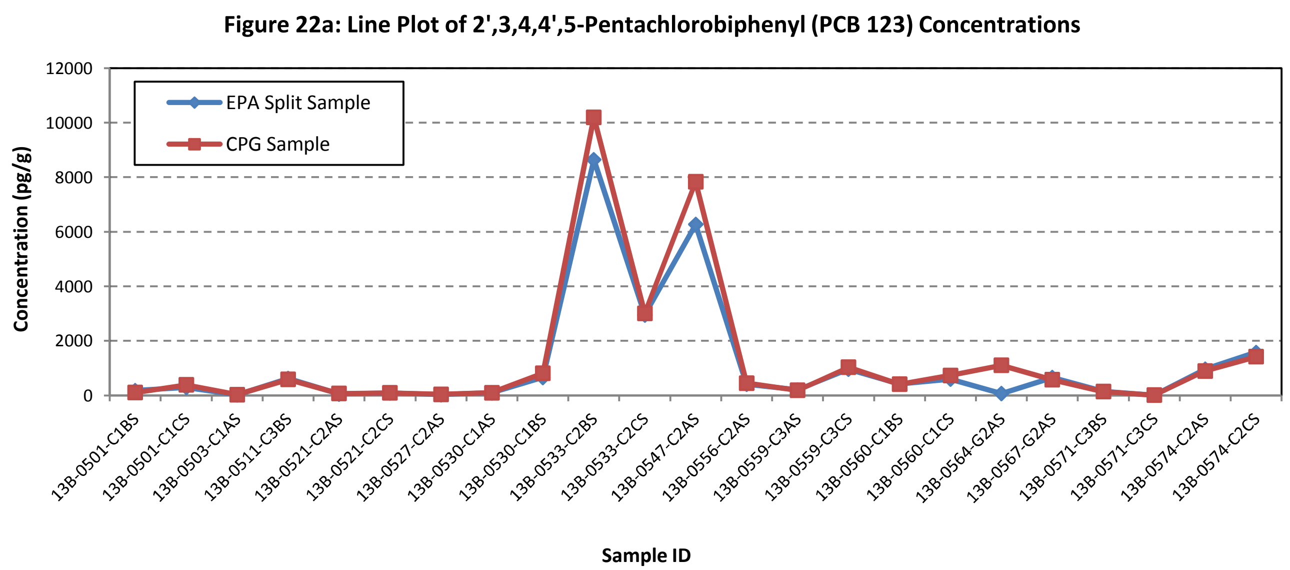


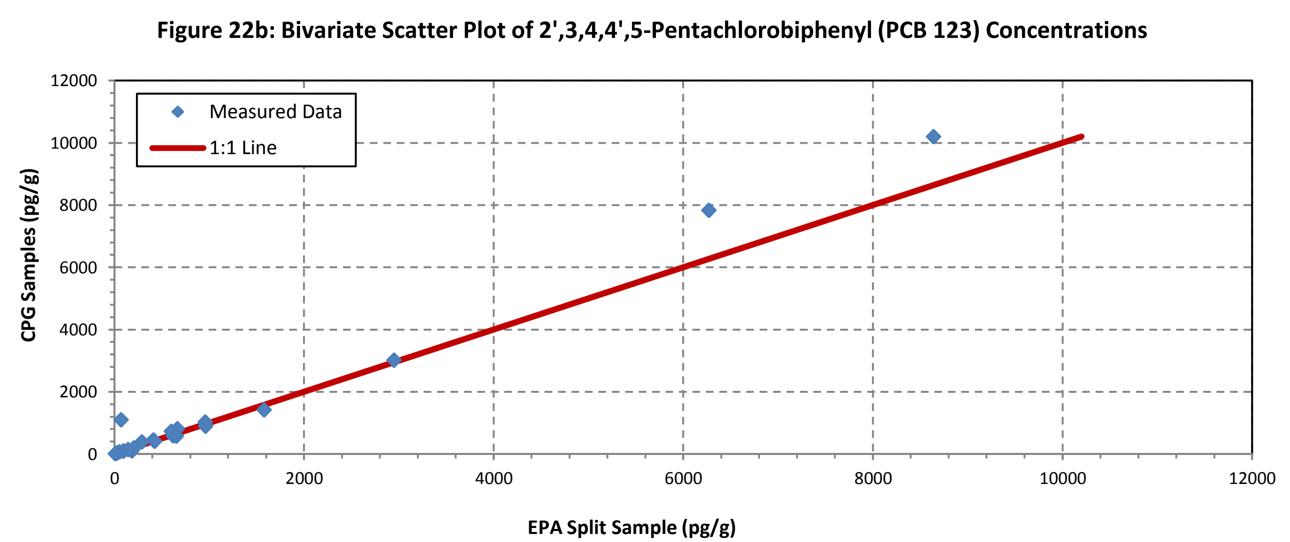
Figure 21c: Line Plot of 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) Percent Differences when EPA and CPG both had Detected Concentrations

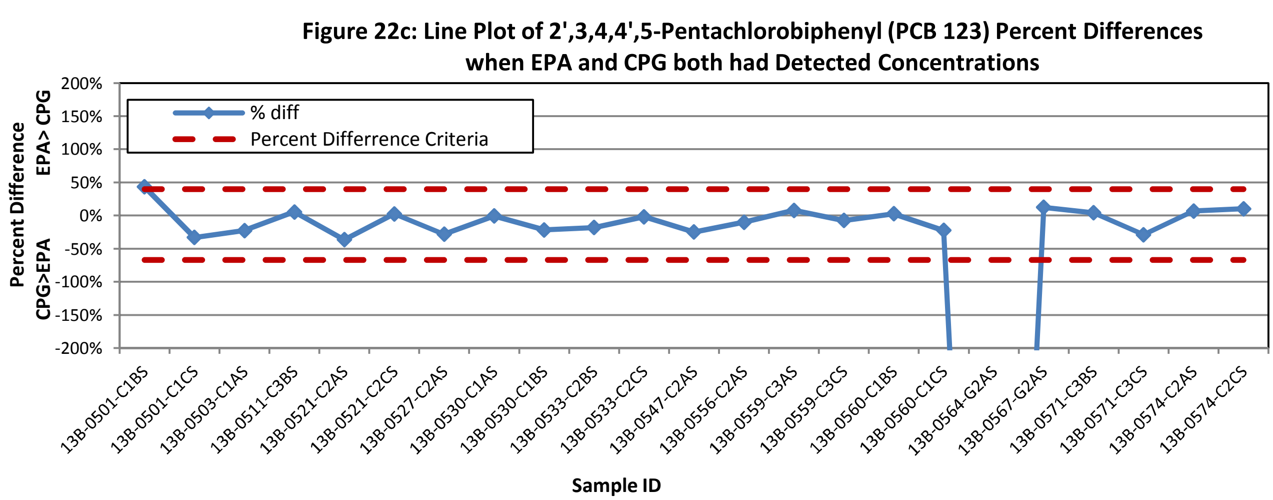


US Army Corps of Engineers	Statistical Plots of 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) Concentrations	Figure 21

pg/g - picogram per gram





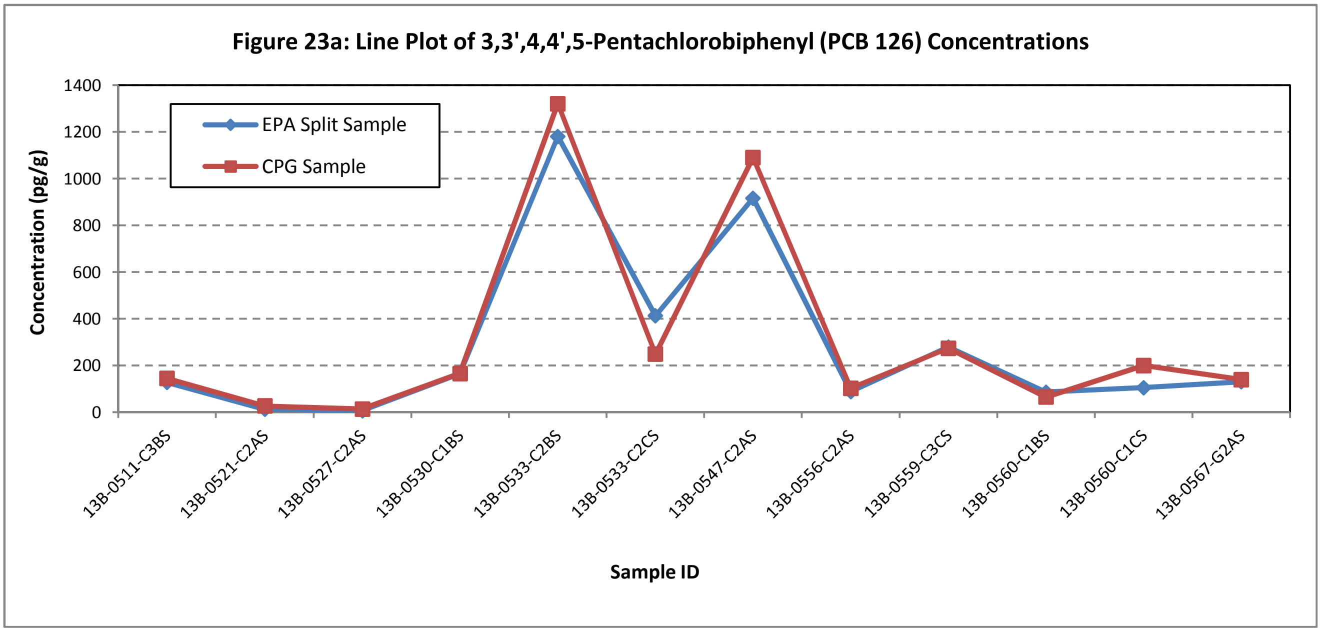


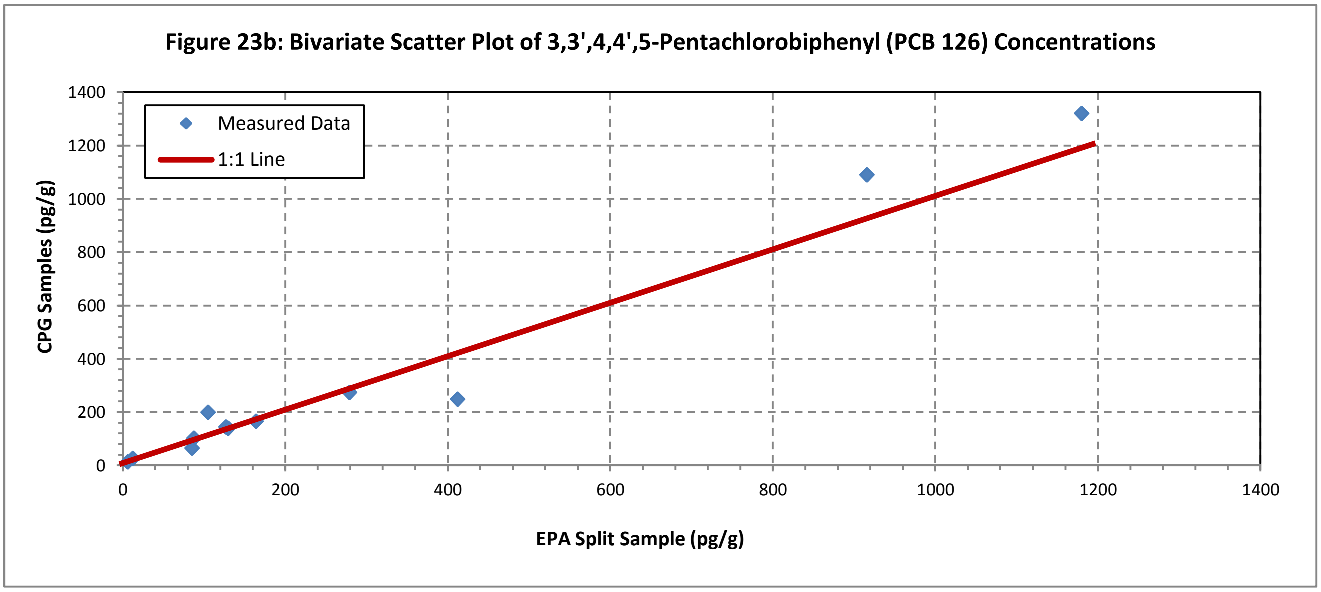
US Army Corps of Engineers®

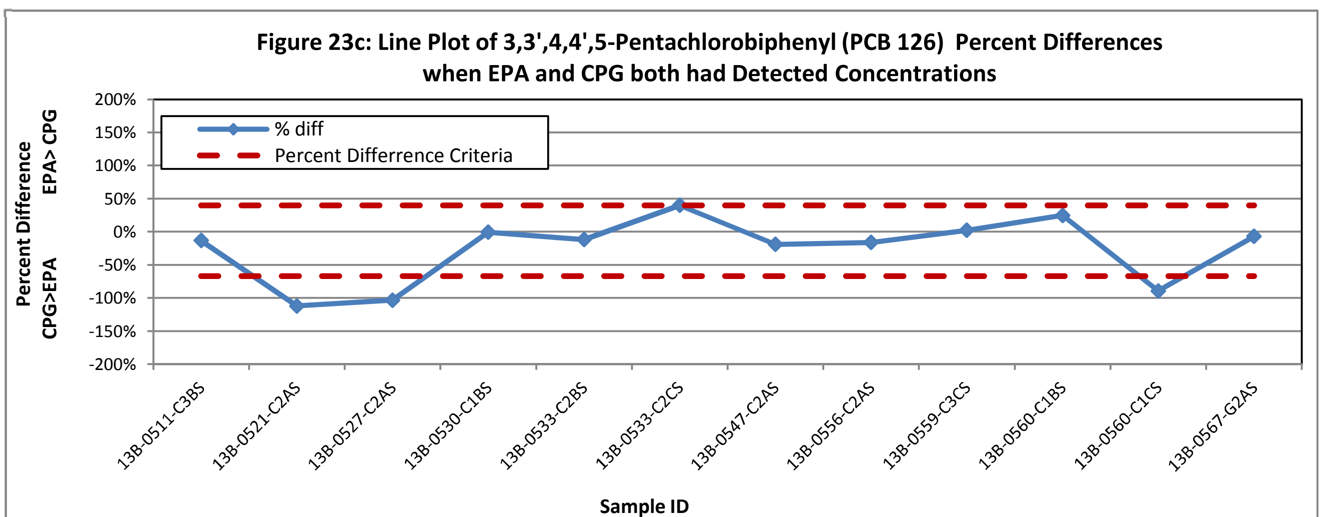
Statistical Plots of 2',3,4,4',5-Pentachlorobiphenyl (PCB 123) Concentrations

Figure 22

pg/g - picogram per gram







US Army Corps of Engineers	**Statistical Plots of 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) Concentrations**	**Figure 23**

pg/g - picogram per gram

Figure 24a: Line Plot of 2,3,3',4,4',5-Hexachlorobiphenyl + 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 156 + PCB 157) Concentrations

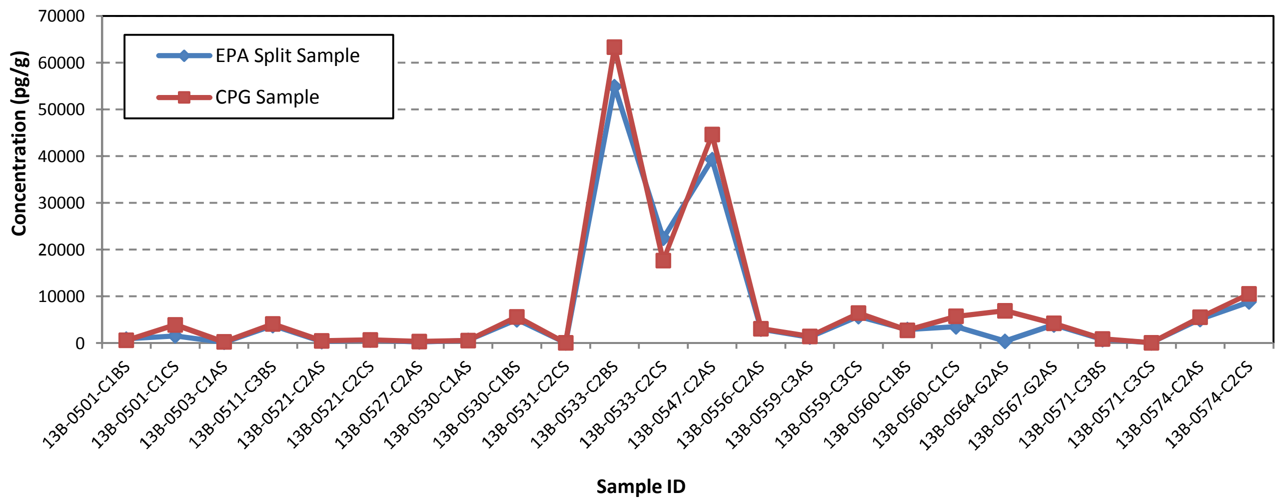


Figure 24b: Bivariate Scatter Plot of 2,3,3',4,4',5-Hexachlorobiphenyl + 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 156 + PCB 157) Concentrations

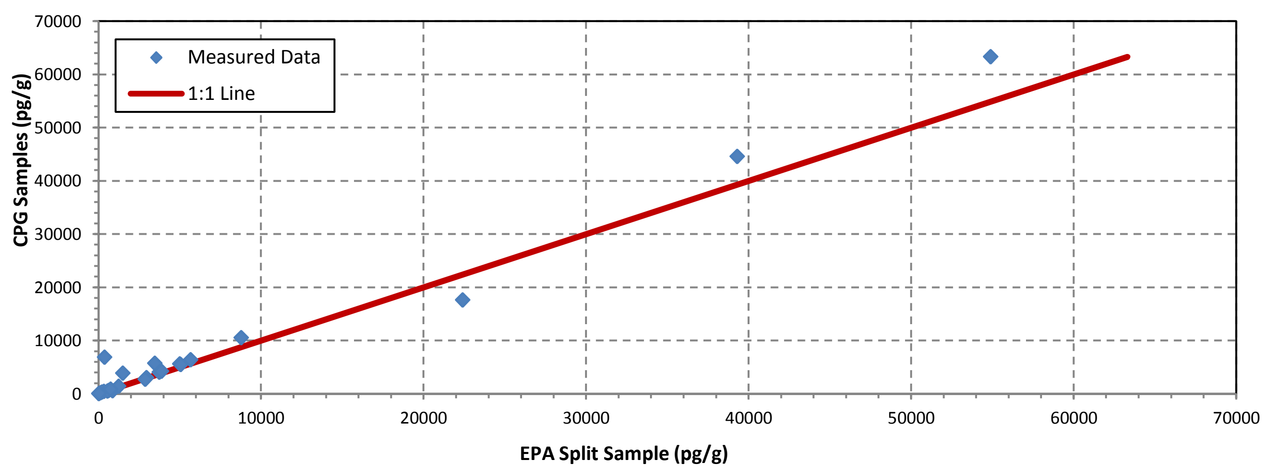
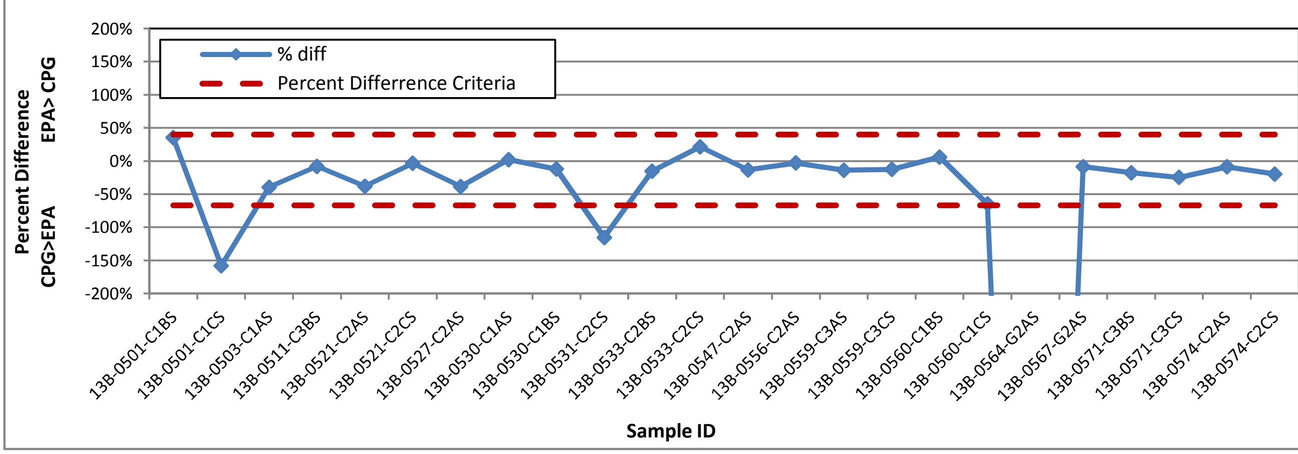
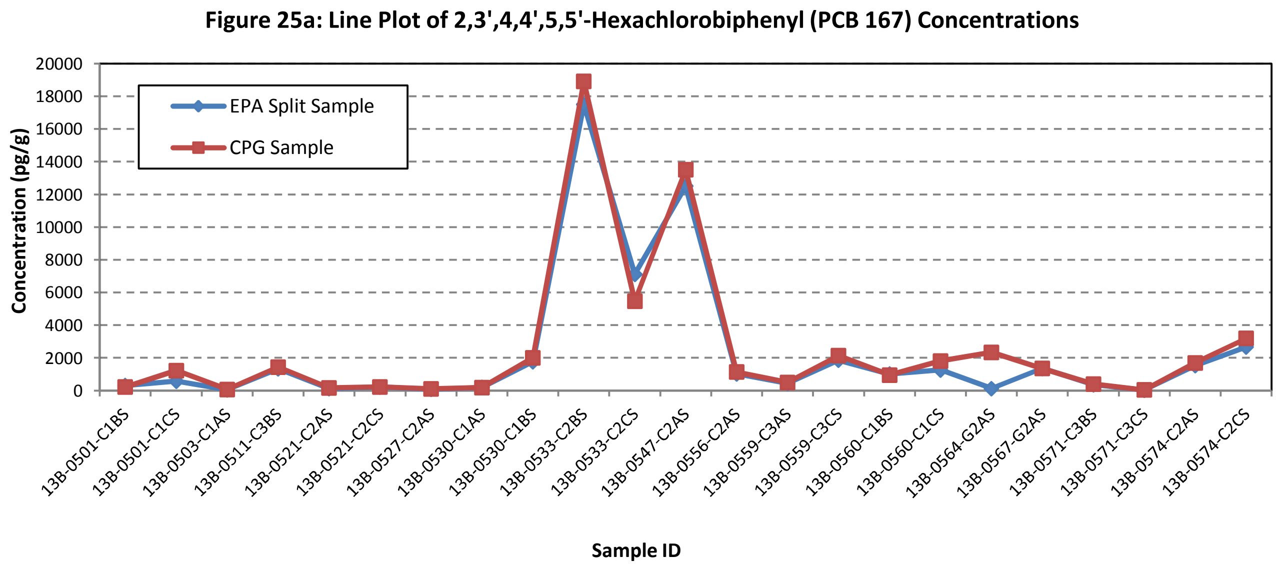


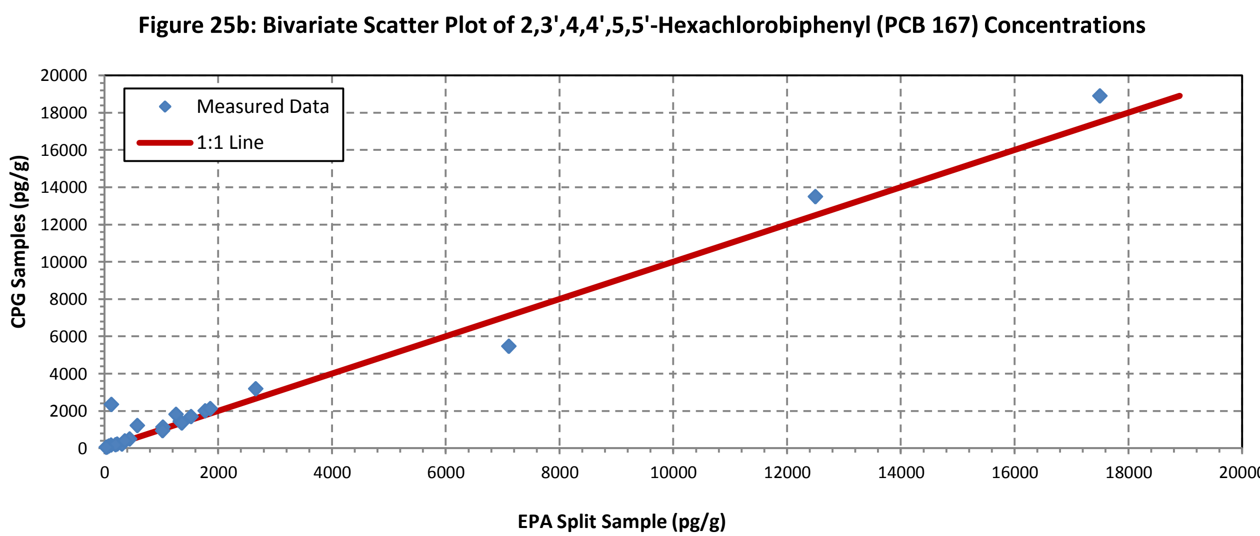
Figure 24c: Line Plot of 2,3,3',4,4',5-Hexachlorobiphenyl + 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 156 + PCB 157) Percent Differences when EPA and CPG both had Detected Concentrations

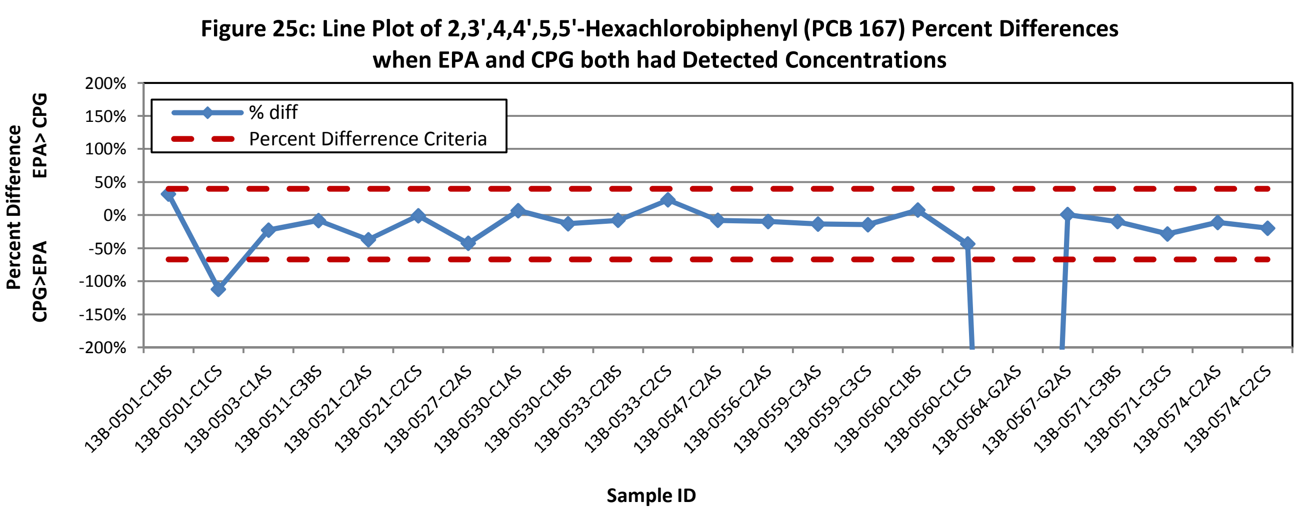


US Army Corps of Engineers	Statistical Plots of 2,3,3',4,4',5-Hexachlorobiphenyl + 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 156 + PCB 157) Concentrations	Figure 24

pg/g - picogram per gram







US Army Corps of Engineers	**Statistical Plots of 2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167) Concentrations**	**Figure 25**

pg/g - picogram per gram

Figure 26a: Line Plot of 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) Concentrations

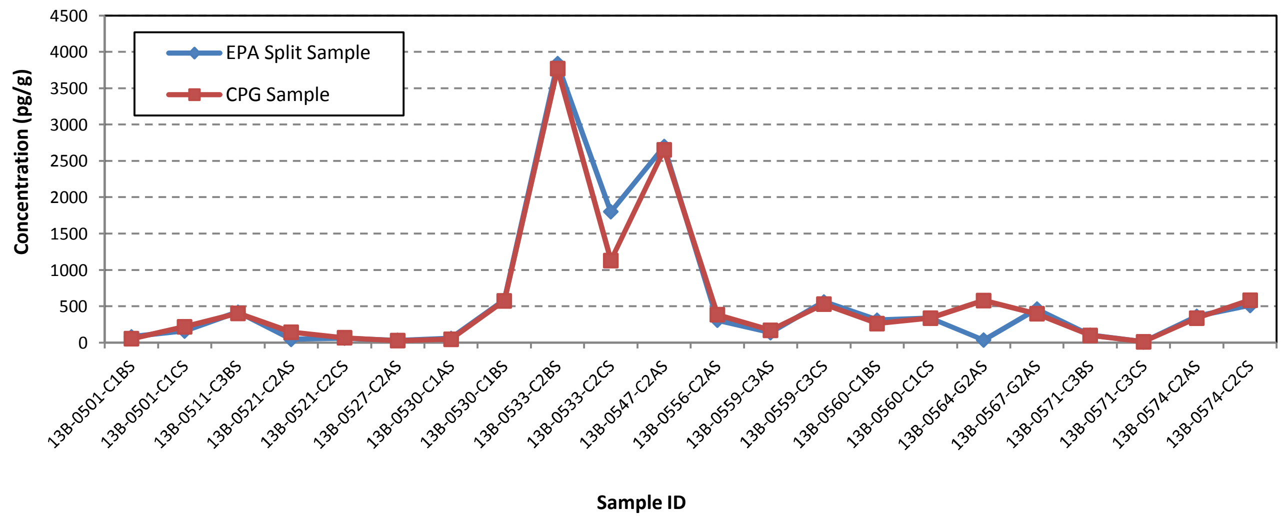


Figure 26b: Bivariate Scatter Plot of 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) Concentrations

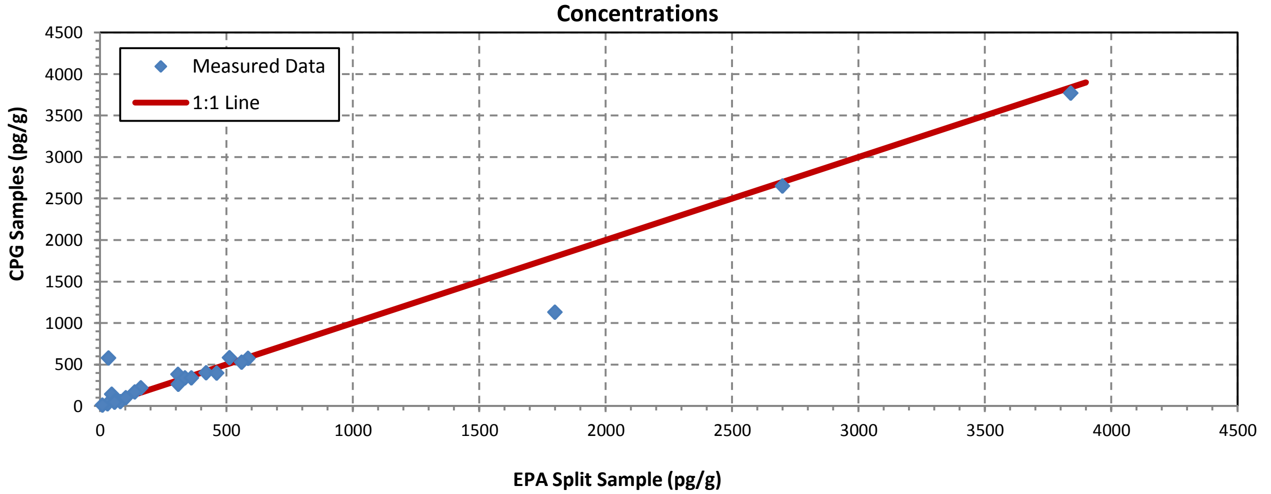
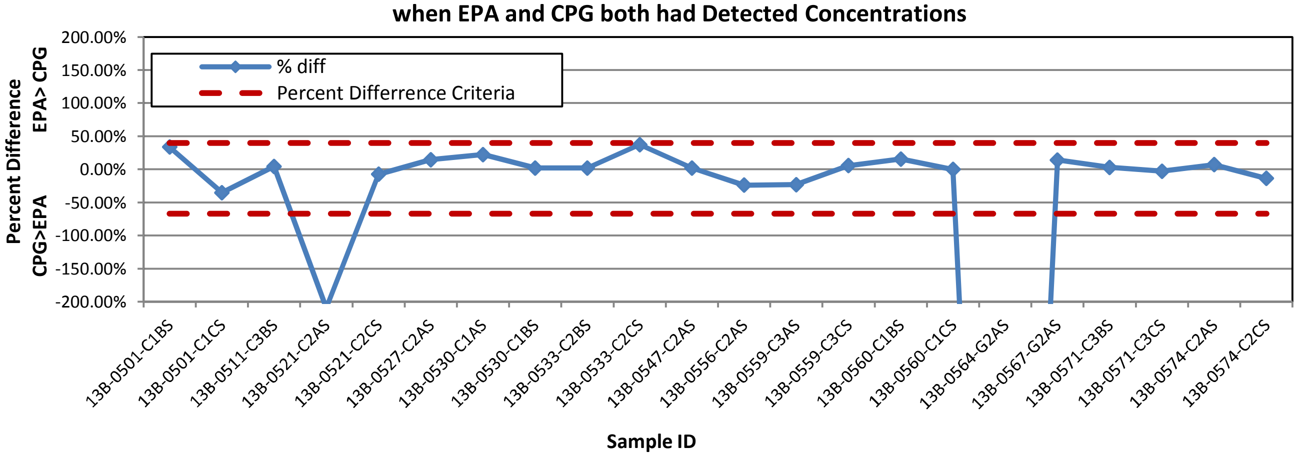


Figure 26c: Line Plot of 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) Percent Differences when EPA and CPG both had Detected Concentrations



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Statistical Plots of 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) Concentrations

Figure 26

pg/g - picogram per gram

Figure 27a: Line Plot of Total Polychlorinated Biphenyls (PCBs) Concentrations

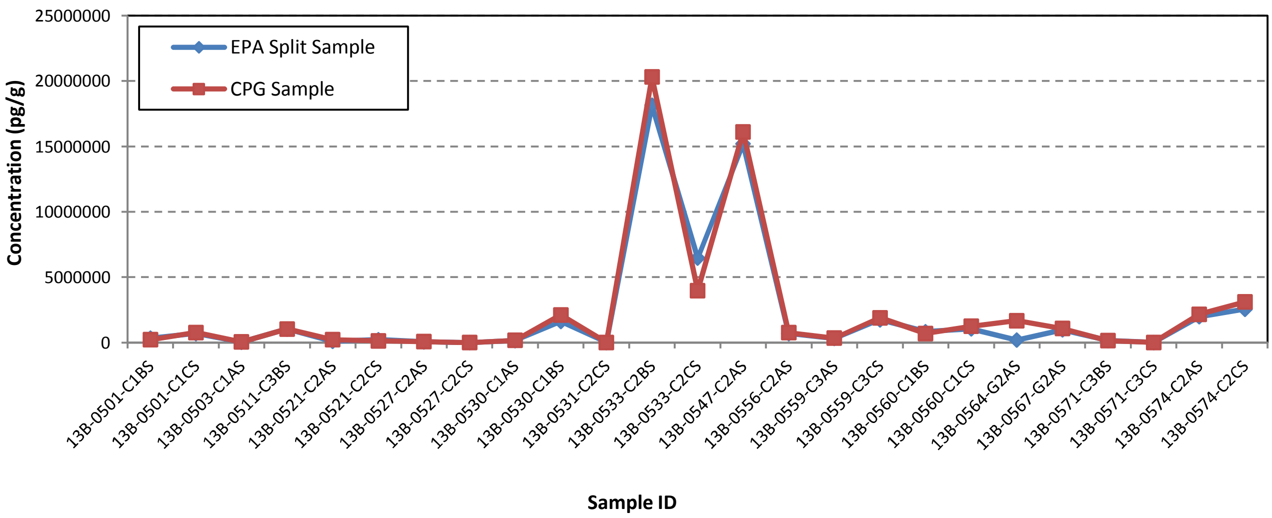


Figure 27b: Bivariate Scatter Plot of Total Polychlorinated Biphenyls (PCBs) Concentrations

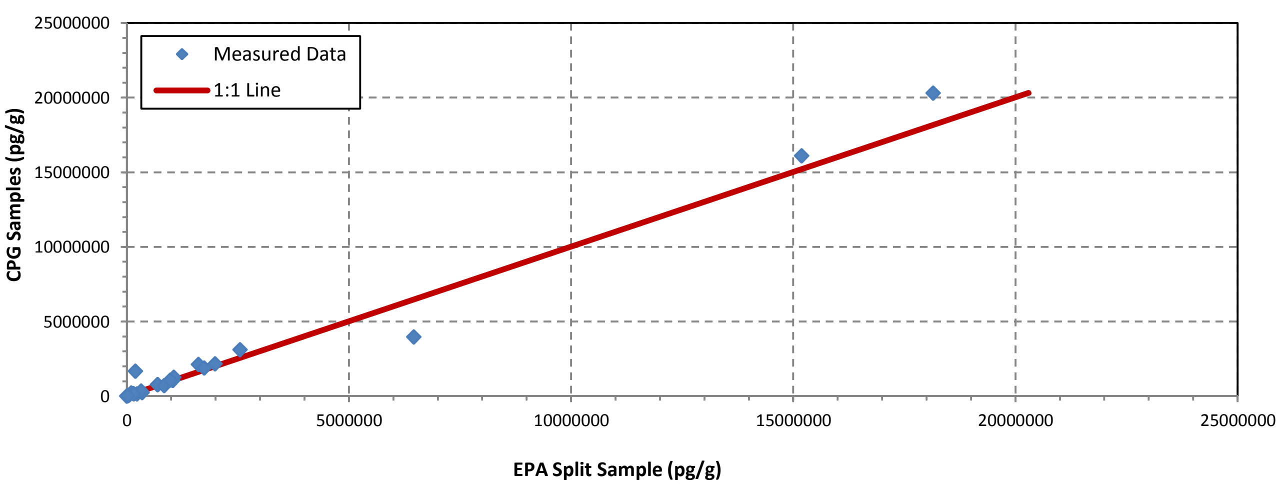
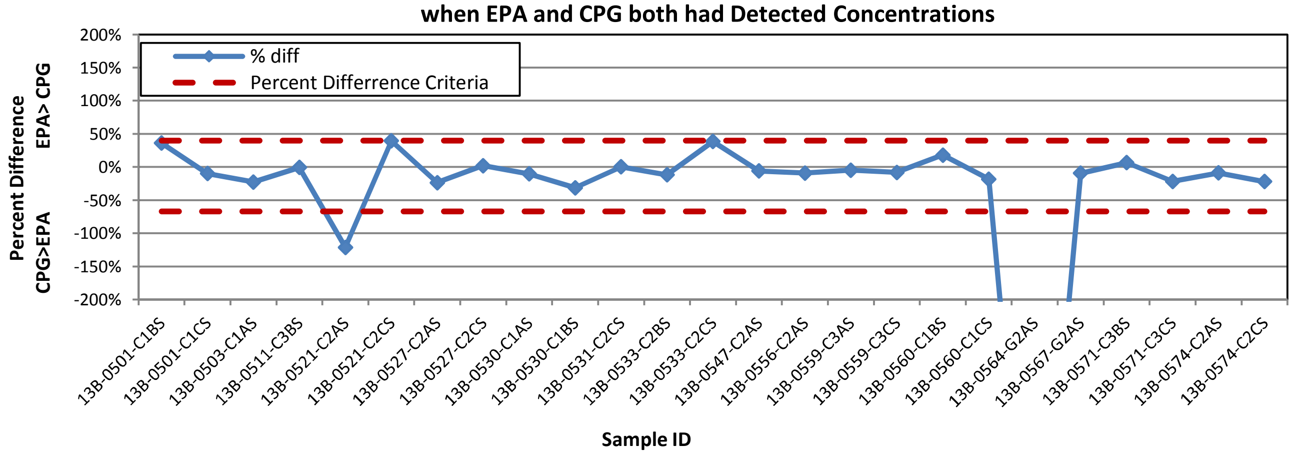


Figure 27c: Line Plot of Total Polychlorinated Biphenyls (PCBs) Percent Differences
when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of Polychlorinated Biphenyls (PCBs) Concentrations	Figure 27

pg/g - picogram per gram

Figure 28a: Line Plot of Anthracene Concentrations

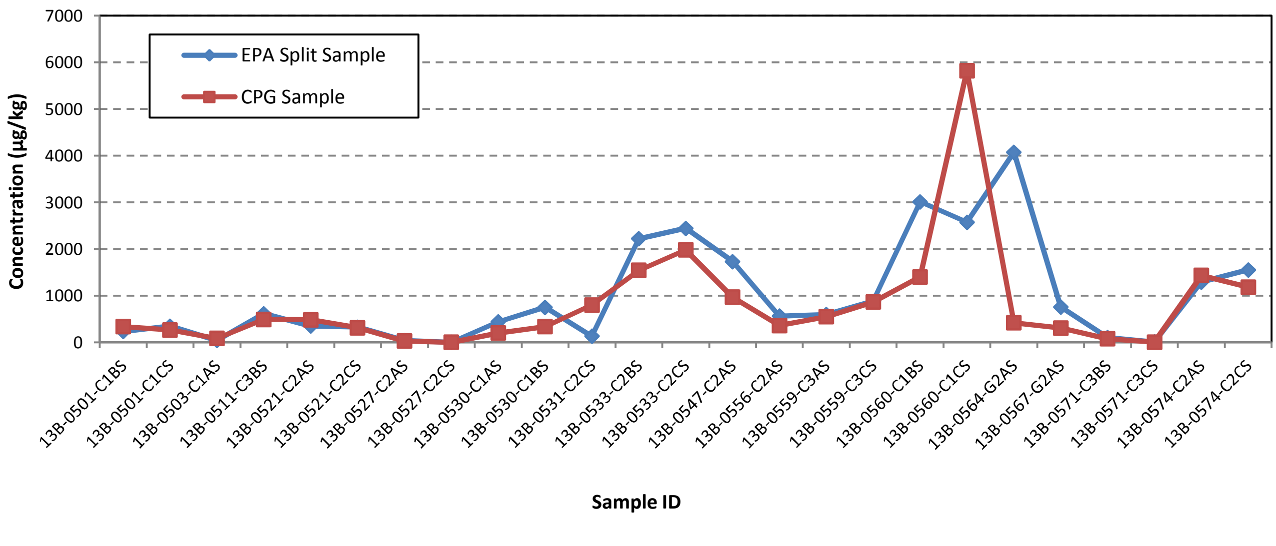


Figure 28b: Bivariate Scatter Plot of Anthracene Concentrations

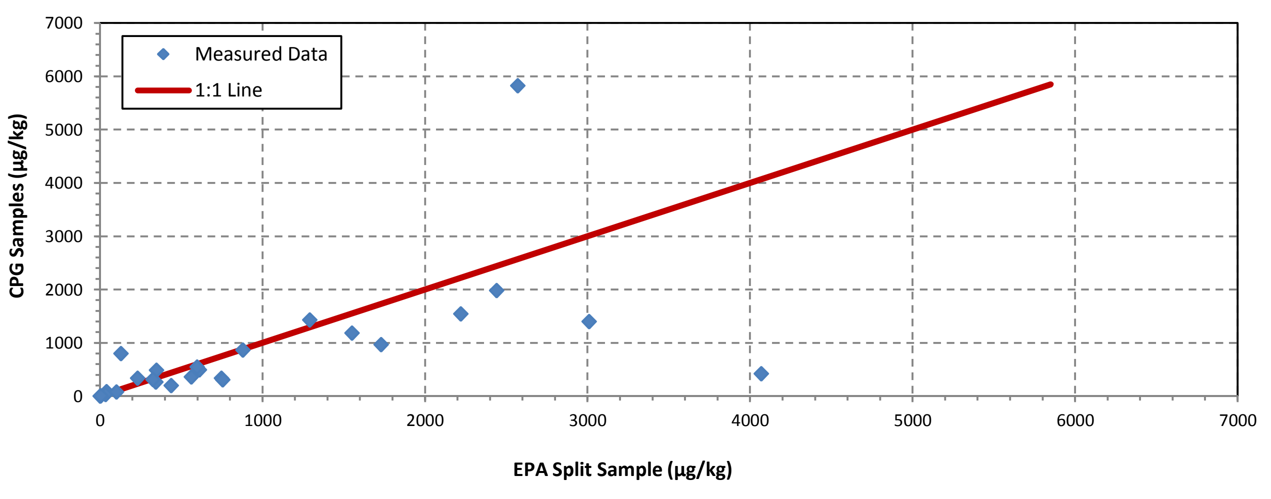
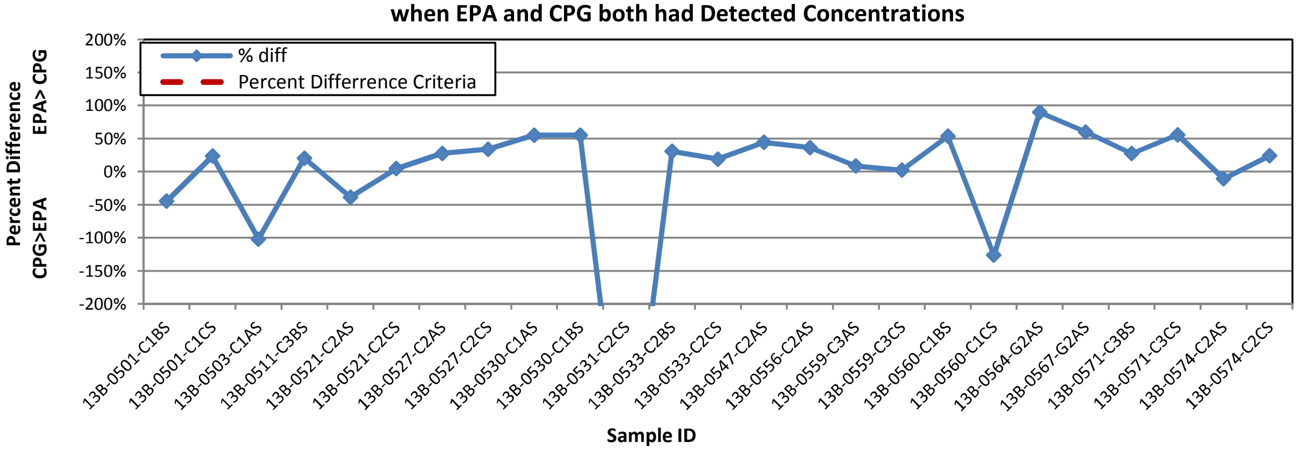
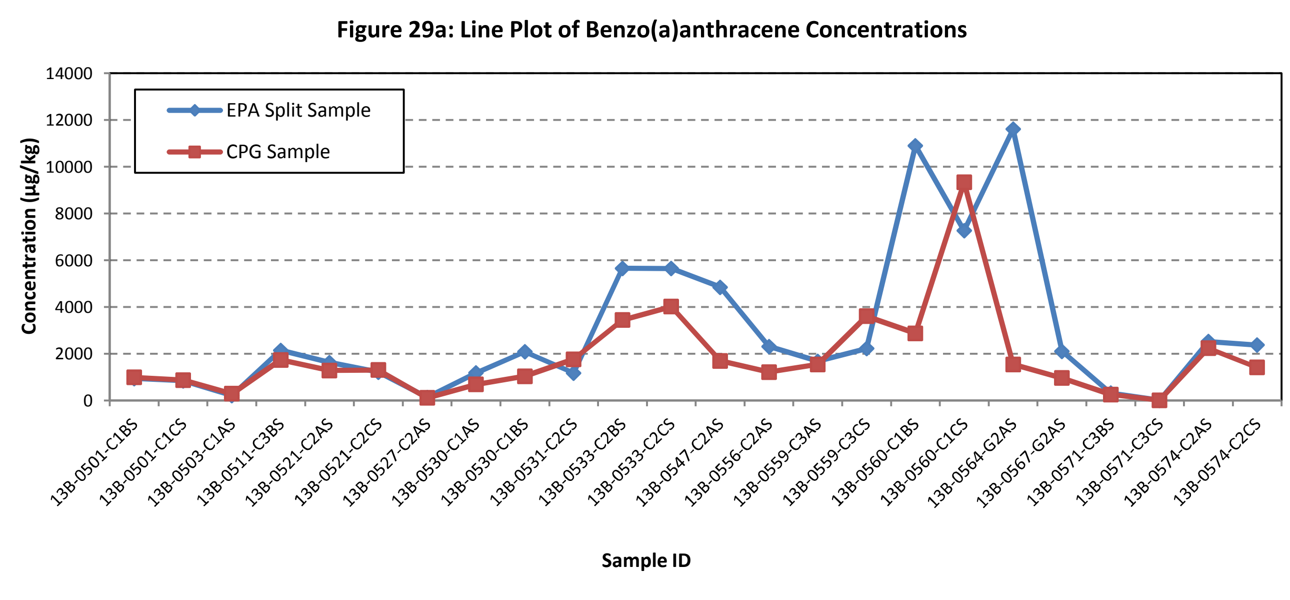


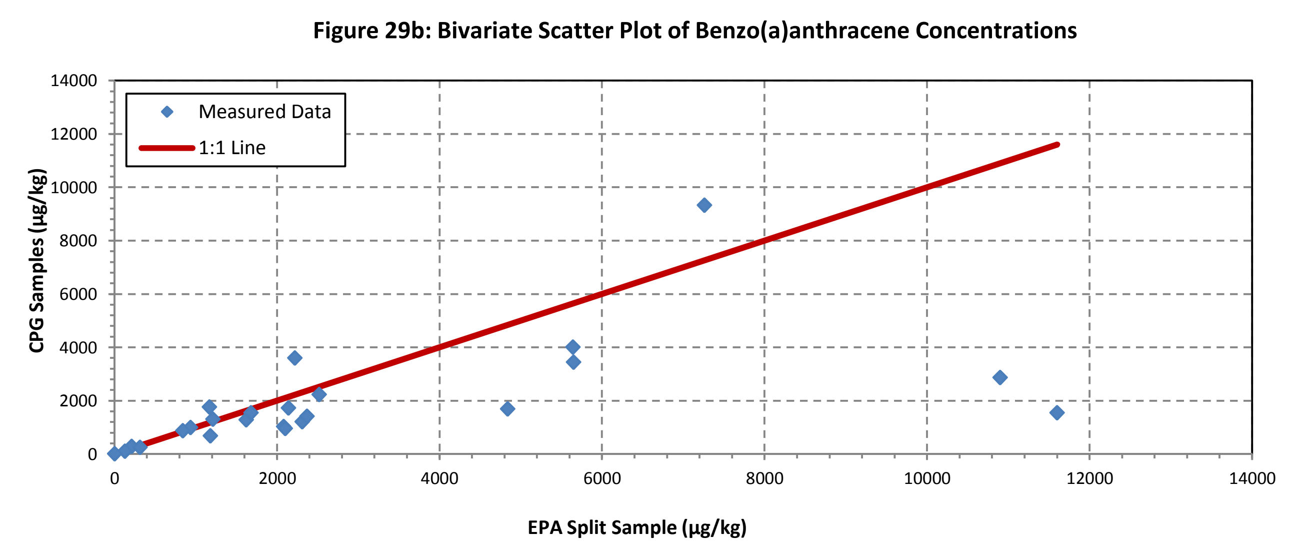
Figure 28c: Line Plot of Anthracene Percent Differences
when EPA and CPG both had Detected Concentrations

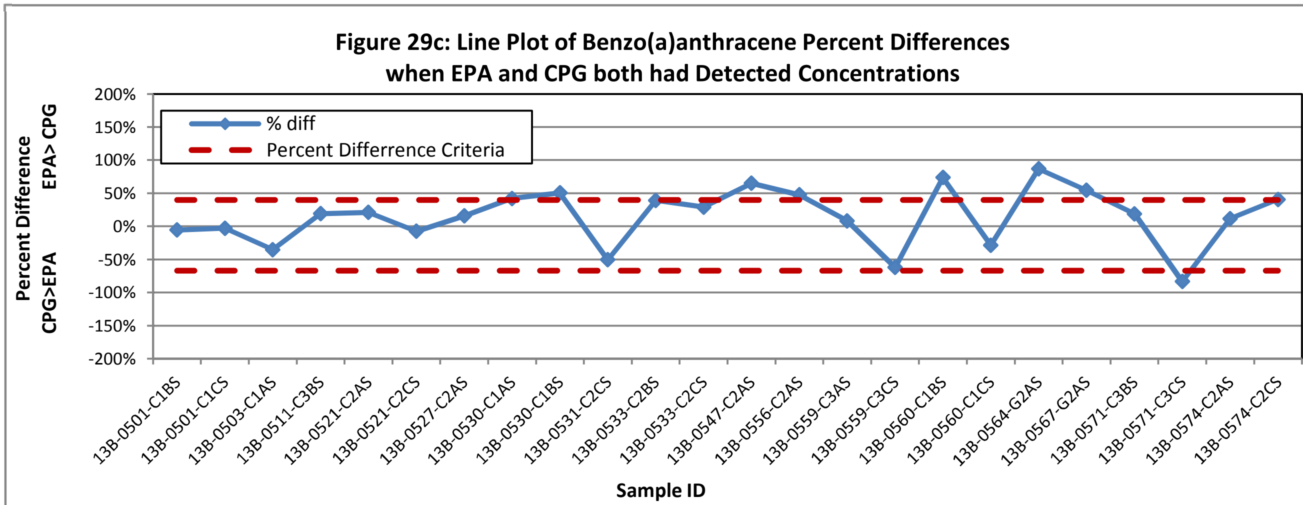


US Army Corps of Engineers	Statistical Plots of Anthracene Concentrations	Figure 28

µg/kg - microgram per kilogram





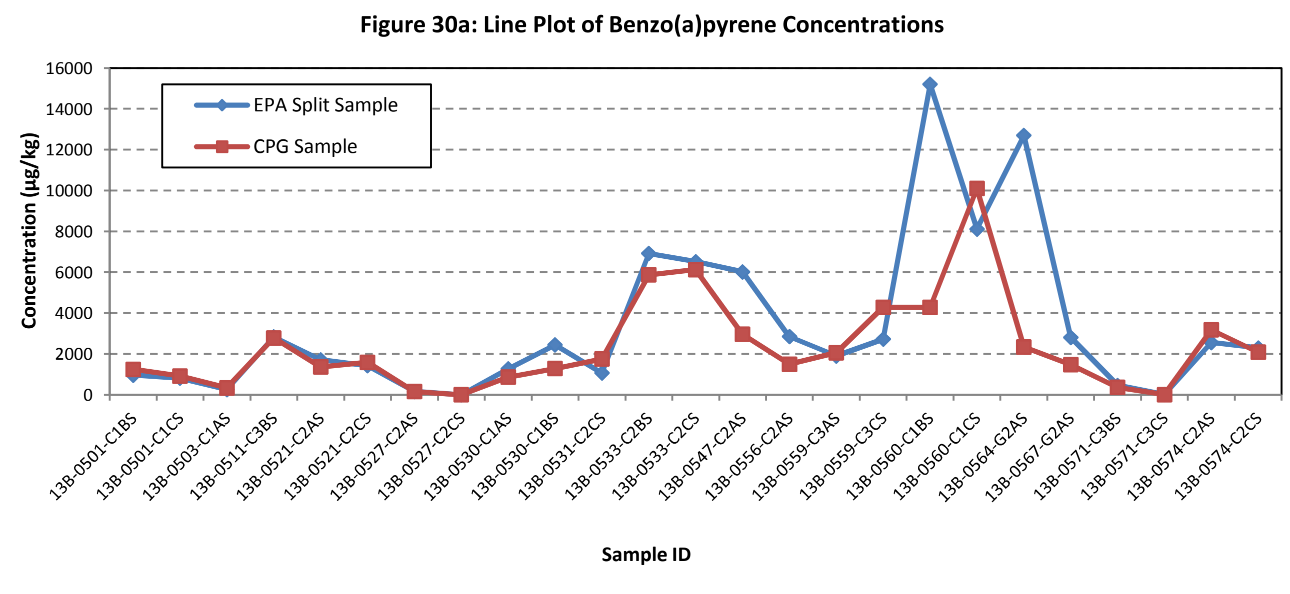


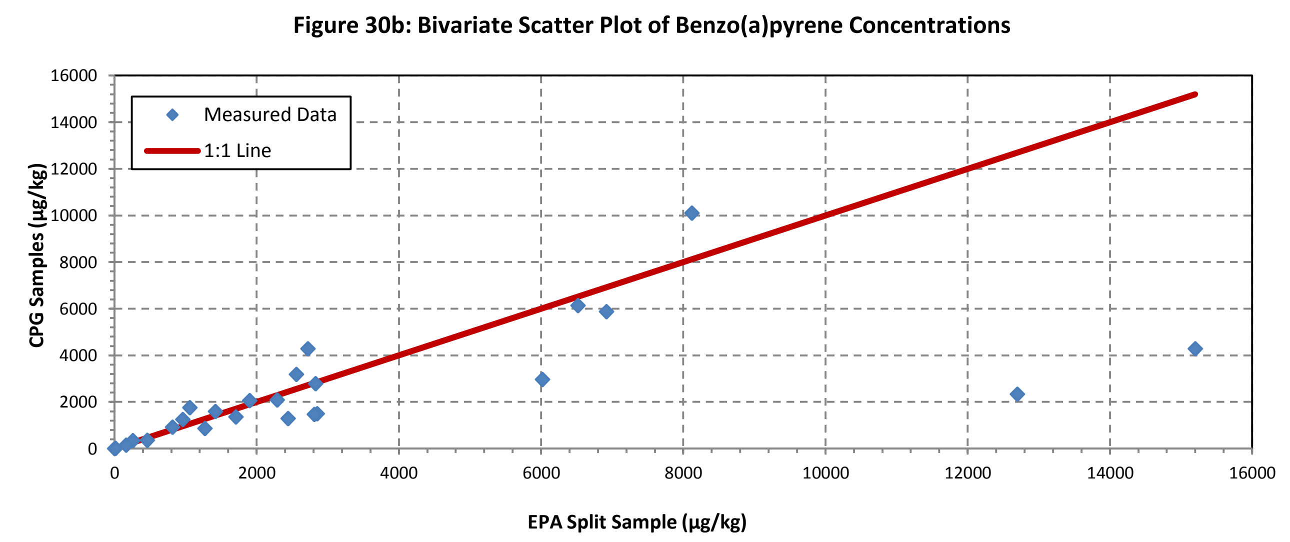
US Army Corps of Engineers

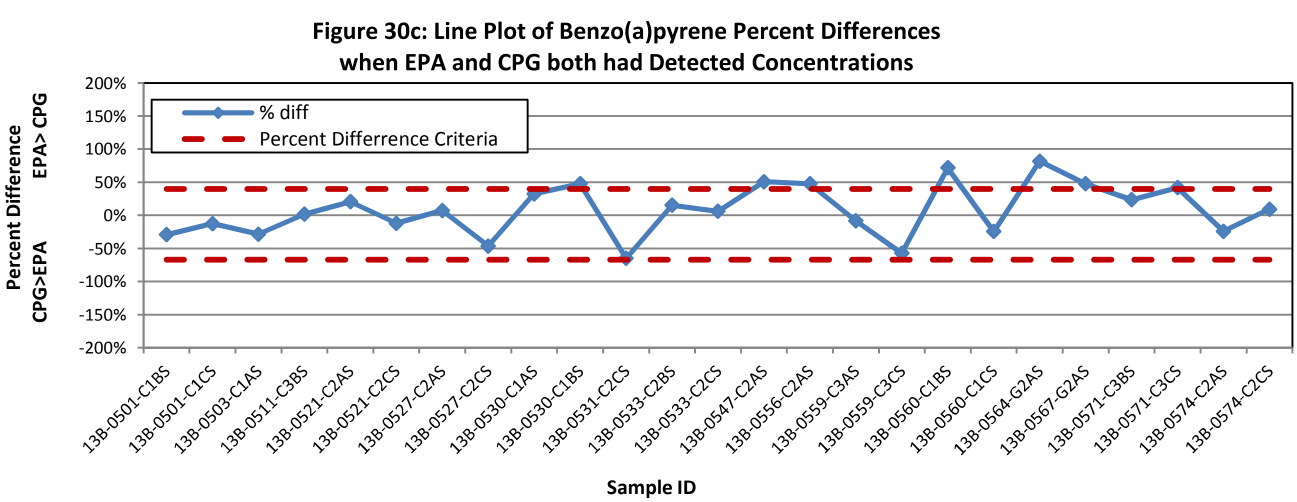
Statistical Plots of Benzo(a)anthracene Concentrations

Figure 29

µg/kg - microgram per kilogram







US Army Corps of Engineers

Statistical Plots of Benzo(a)pyrene Concentrations | **Figure 30**

µg/kg - microgram per kilogram

Figure 31a: Line Plot of Chrysene Concentrations

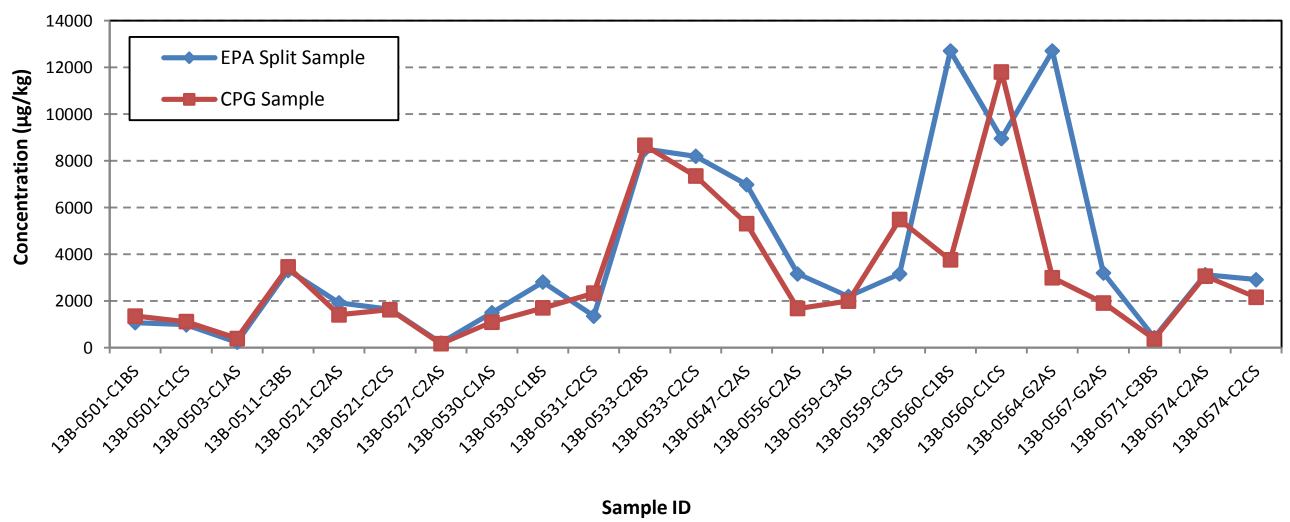


Figure 31b: Bivariate Scatter Plot of Chrysene Concentrations

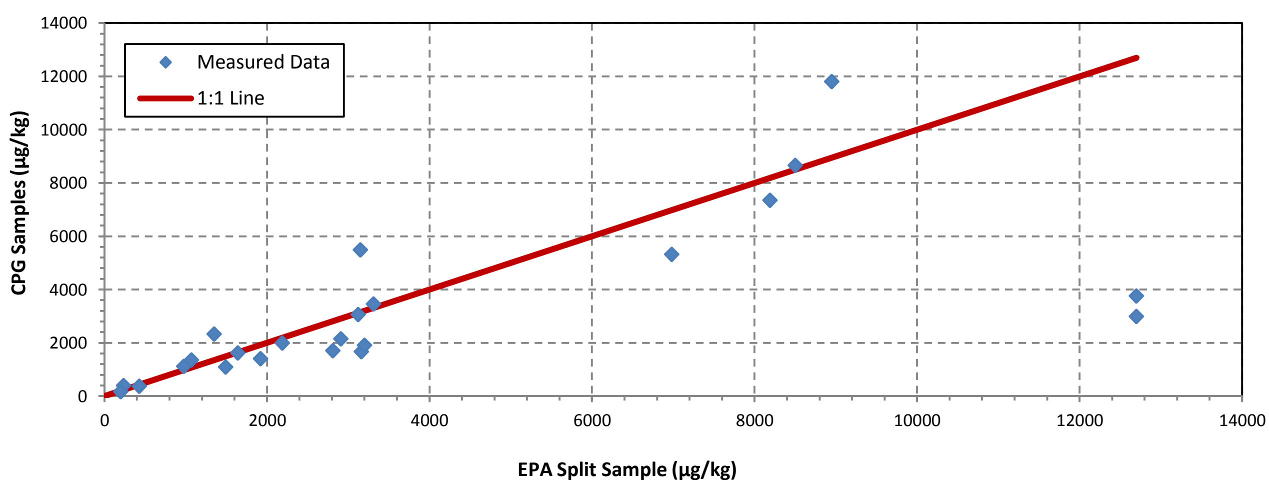
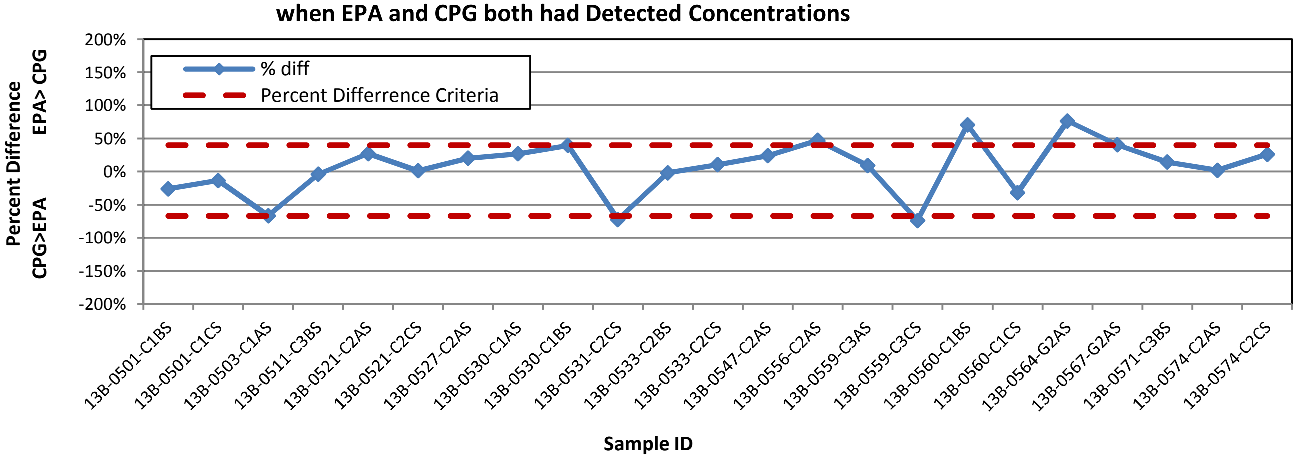


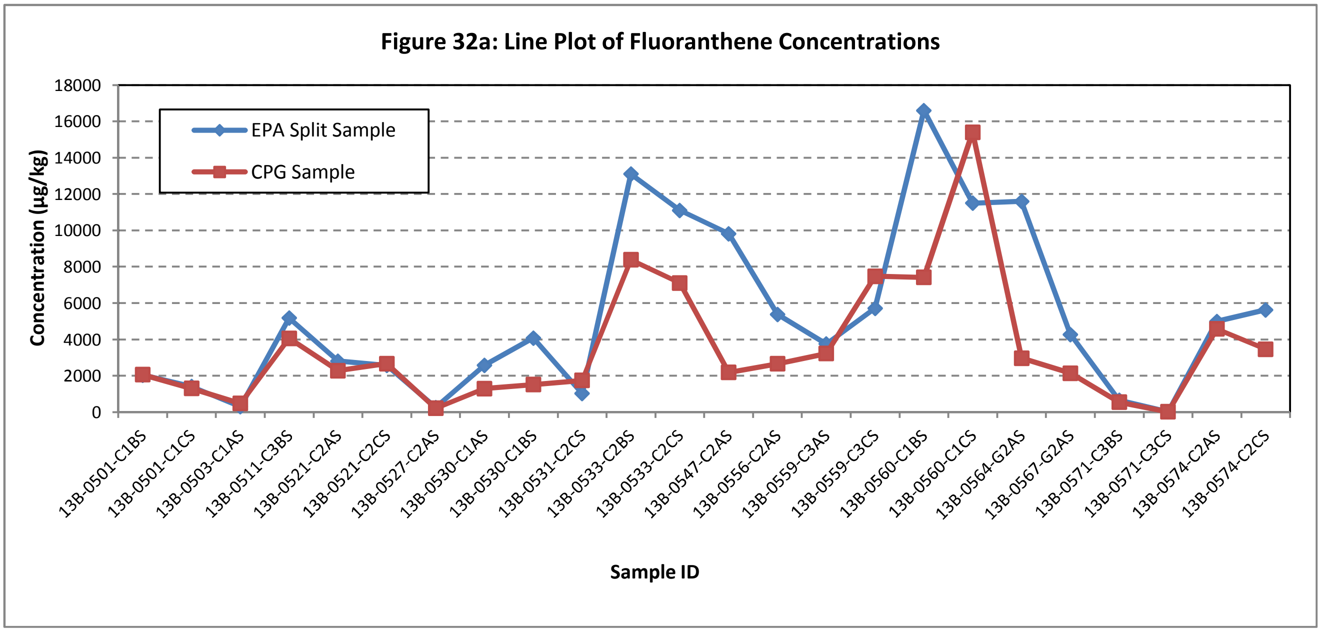
Figure 31c: Line Plot of Chrysene Percent Differences when EPA and CPG both had Detected Concentrations

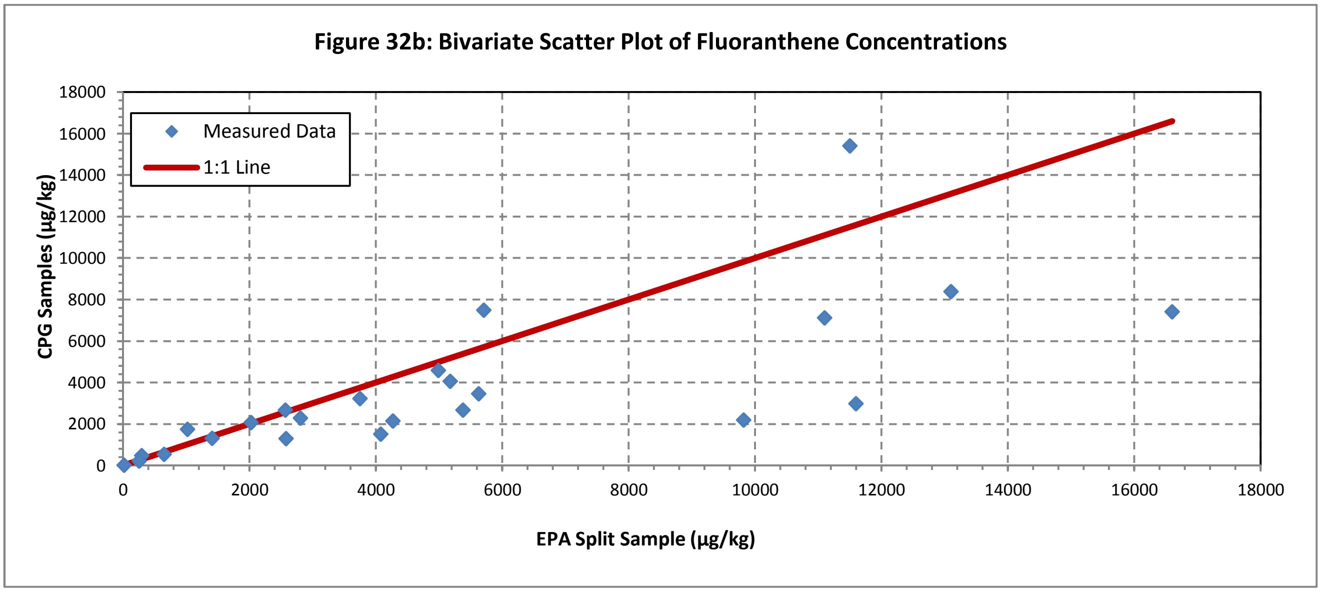


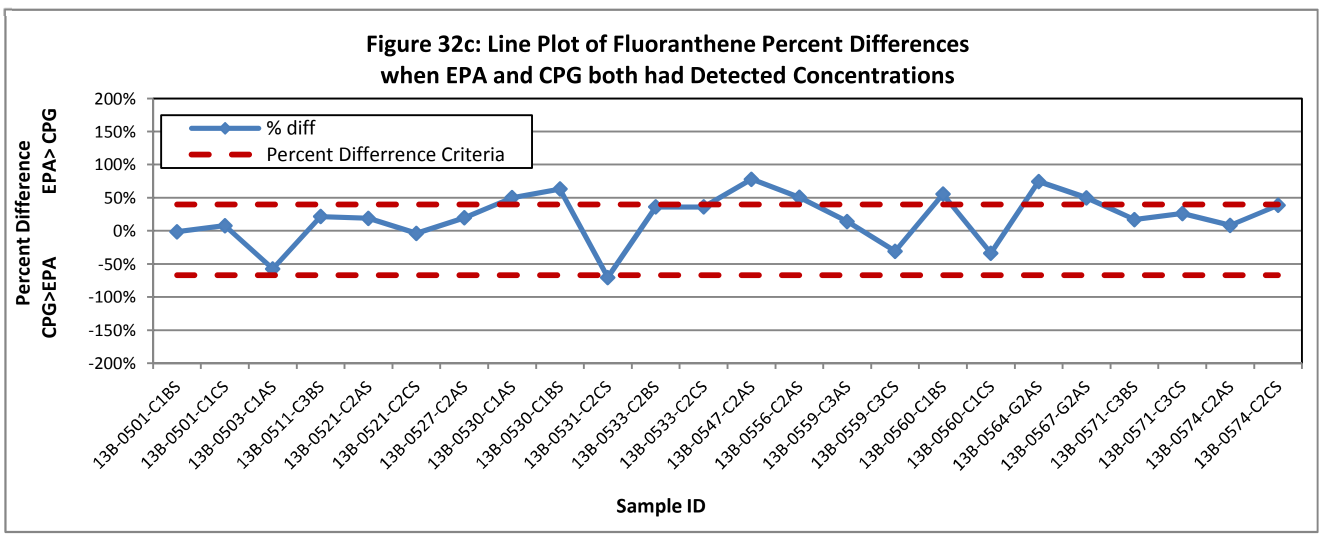
US Army Corps of Engineers

Statistical Plots of Chrysene Concentrations | **Figure 31**

µg/kg - microgram per kilogram

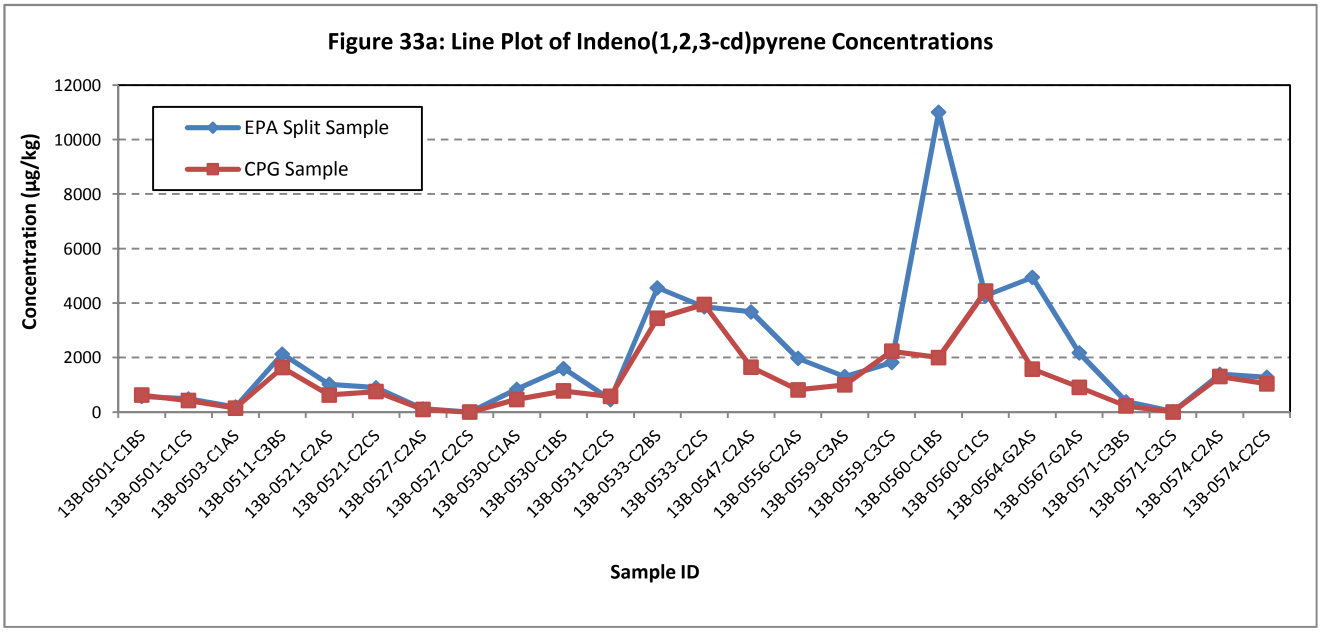


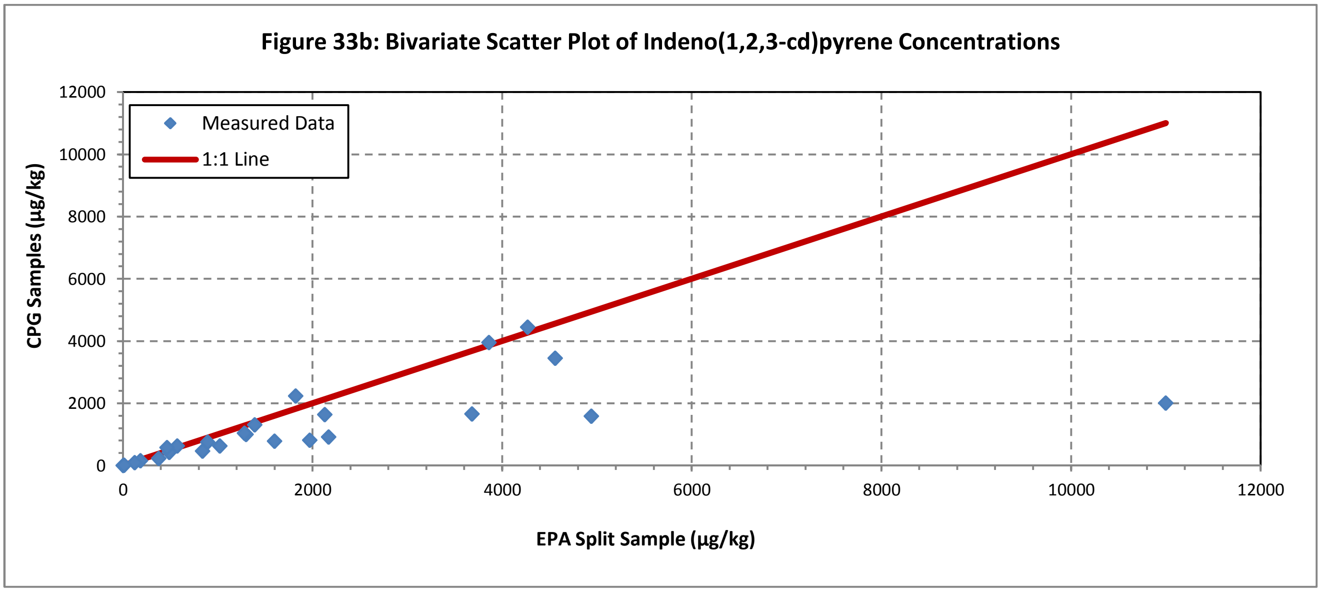


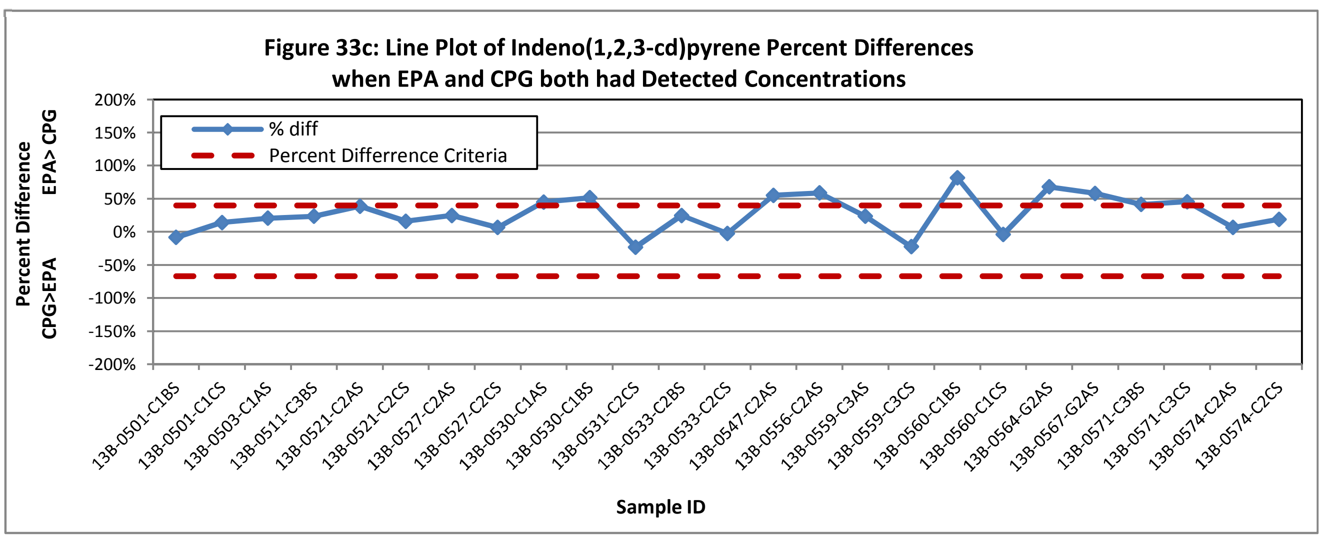


US Army Corps of Engineers®	**Statistical Plots of Fluoranthene Concentrations**	**Figure 32**

µg/kg - microgram per kilogram







US Army Corps of Engineers

Statistical Plots of Indeno(1,2,3-cd)pyrene Concentrations | **Figure 33**

µg/kg - microgram per kilogram

Figure 34a: Line Plot of Naphthalene Concentrations

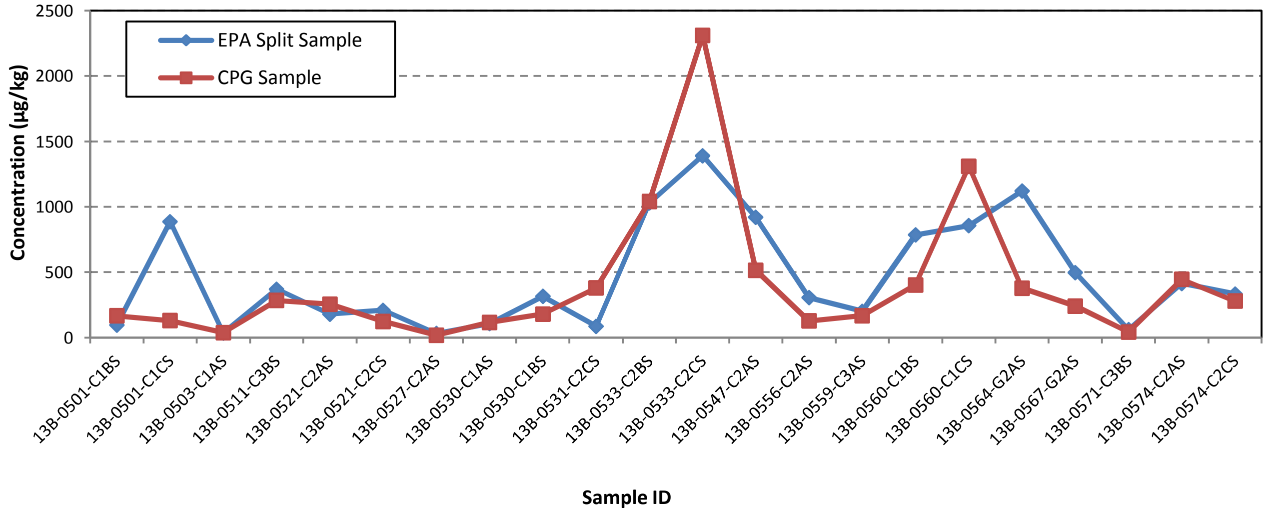


Figure 34b: Bivariate Scatter Plot of Naphthalene Concentrations

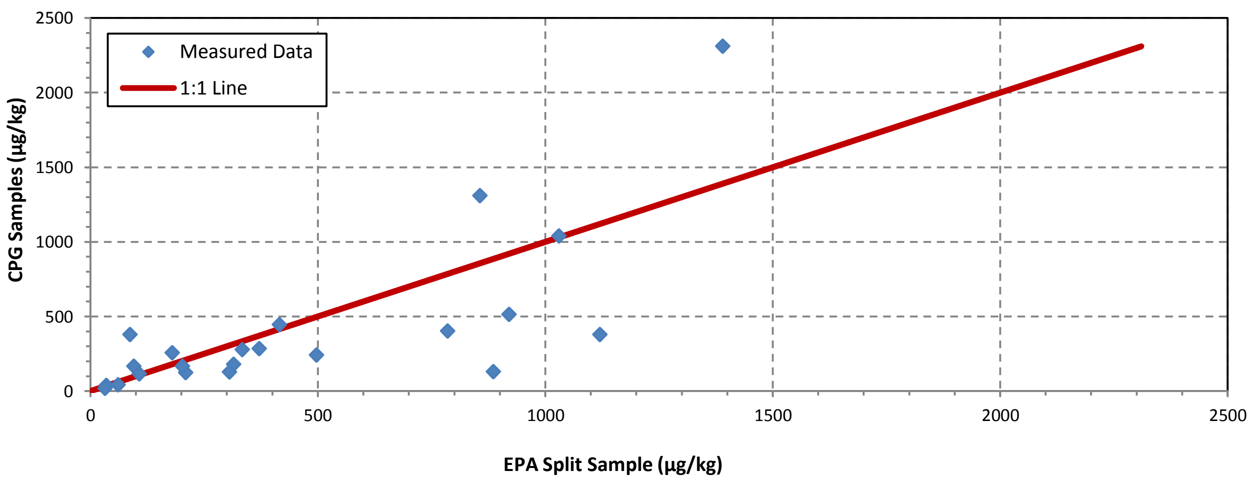
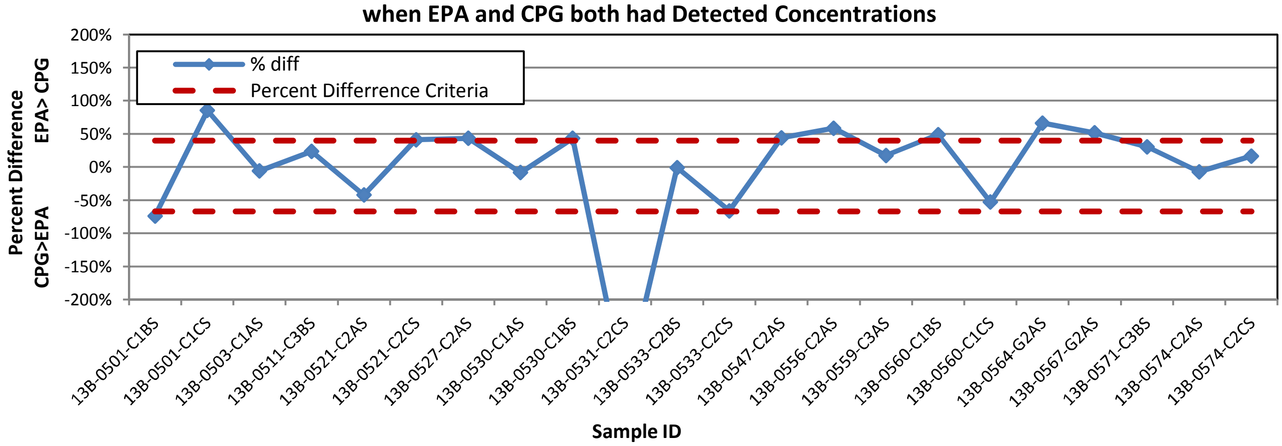


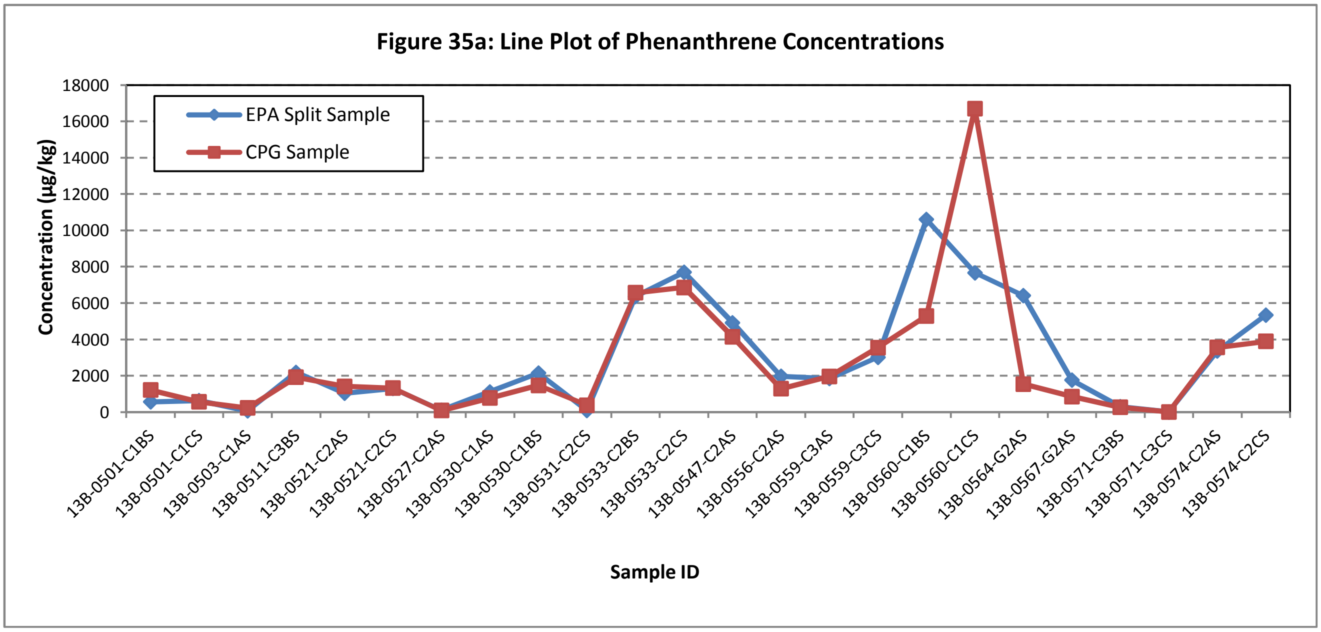
Figure 34c: Line Plot of Naphthalene Percent Differences when EPA and CPG both had Detected Concentrations

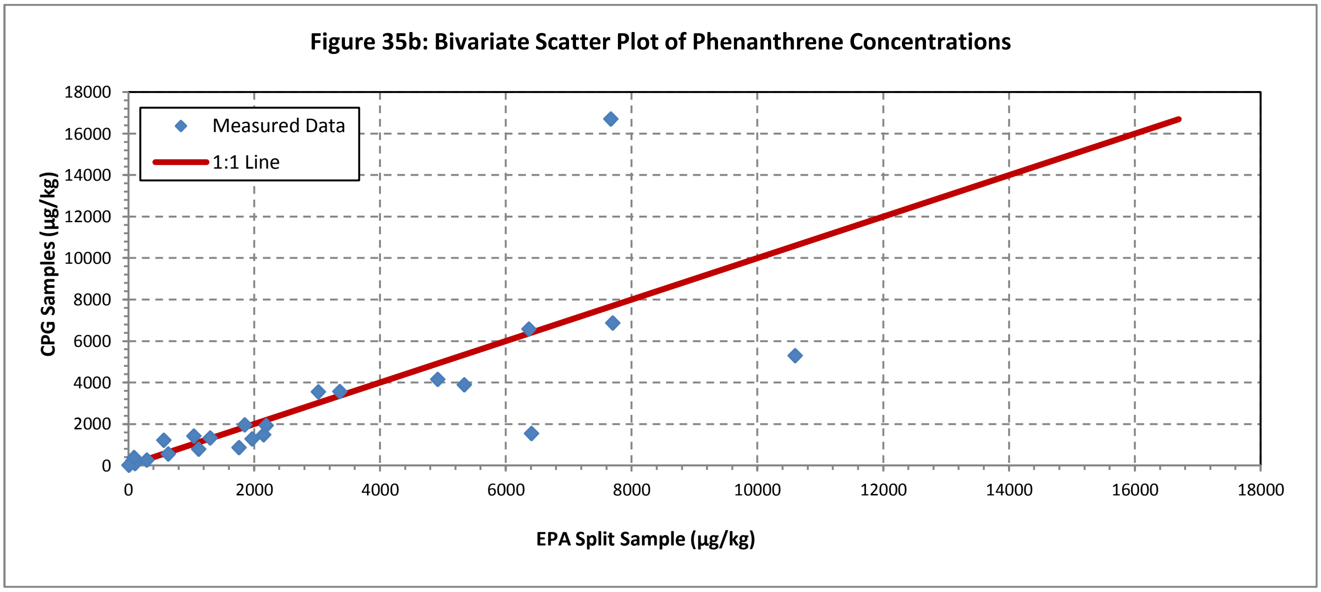


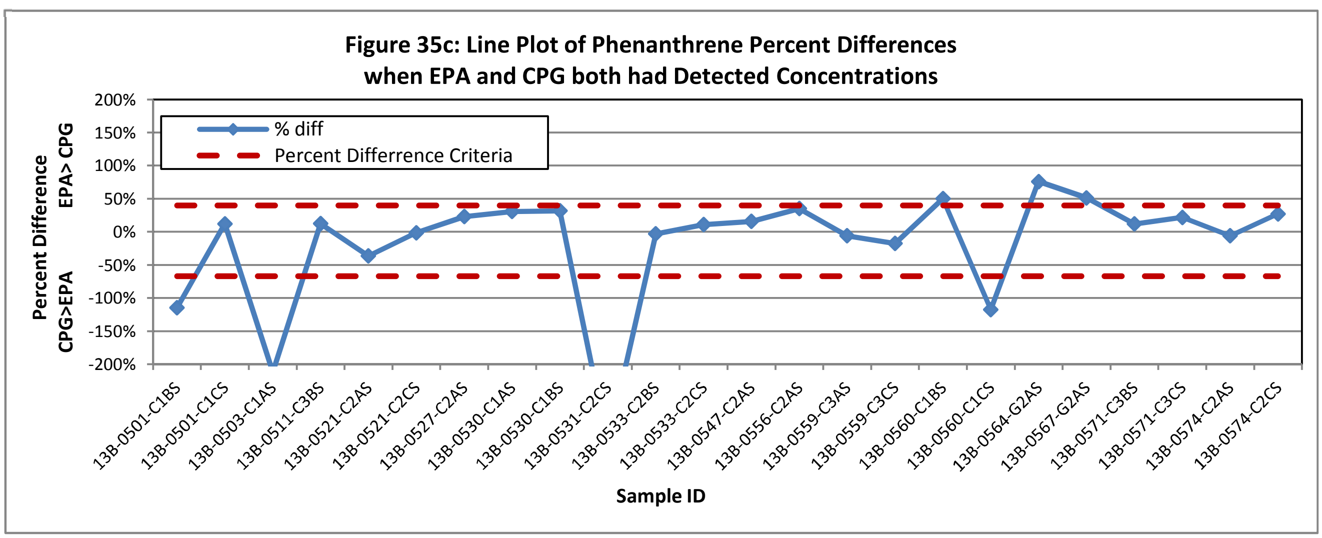
US Army Corps of Engineers

US Army Corps of Engineers	**Statistical Plots of Naphthalene Concentrations**	**Figure 34**

µg/kg - microgram per kilogram







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Statistical Plots of Phenanthrene Concentrations | **Figure 35**

µg/kg - microgram per kilogram

Figure 36a: Line Plot of Pyrene Concentrations

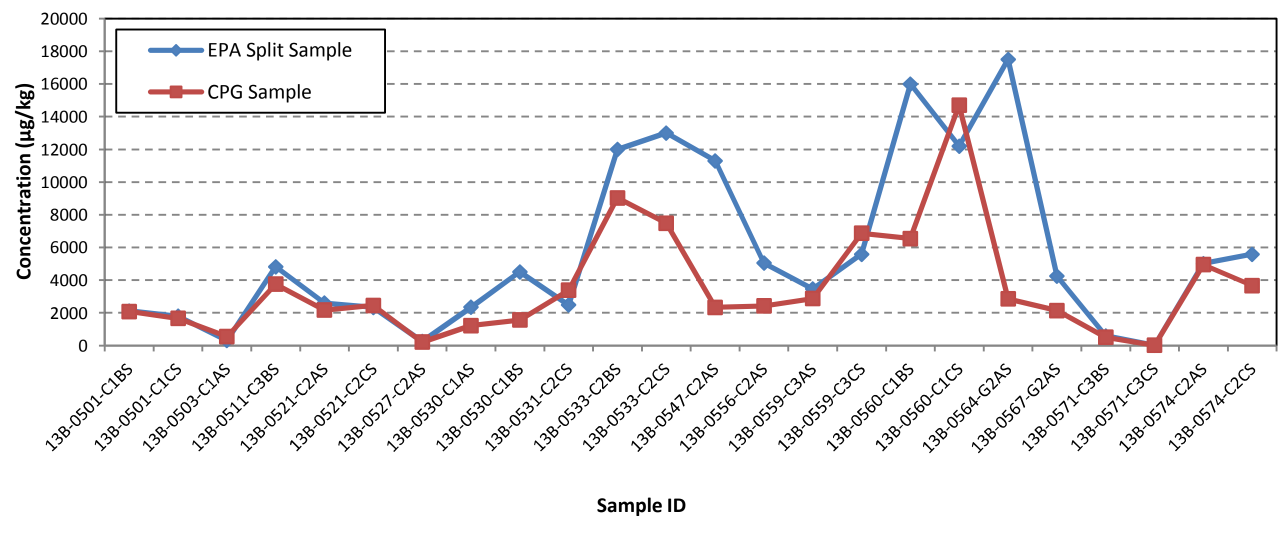


Figure 36b: Bivariate Scatter Plot of Pyrene Concentrations

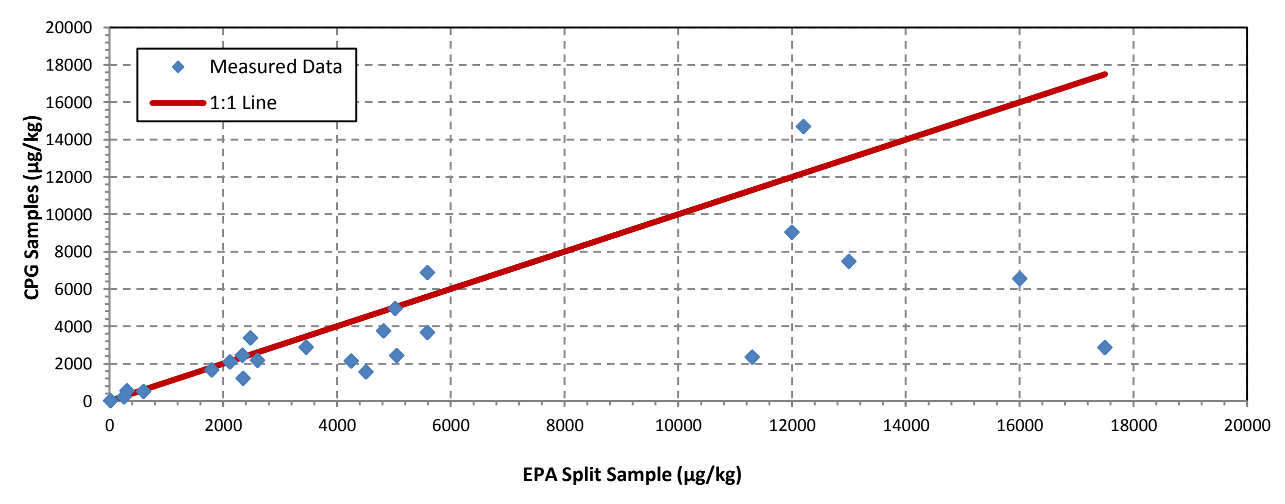
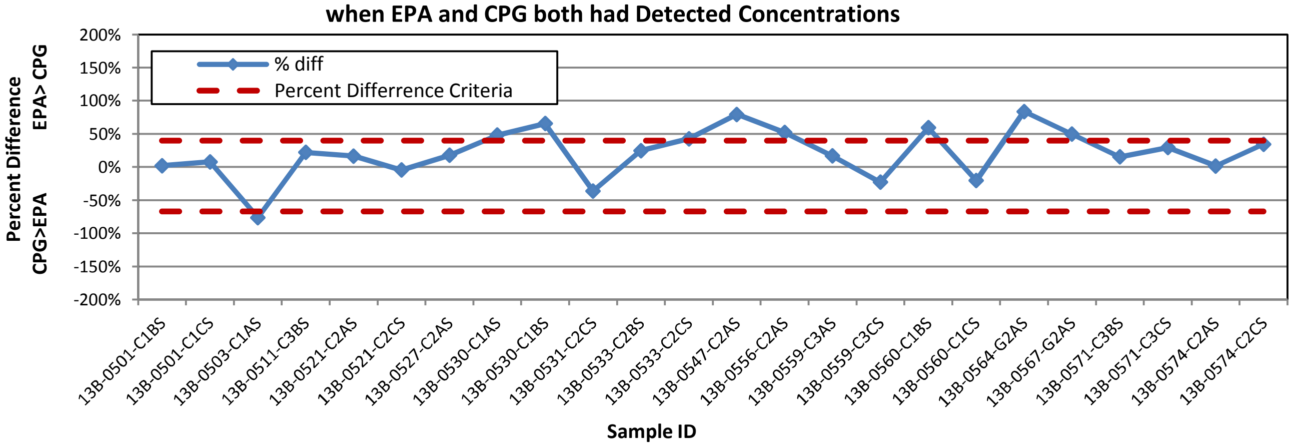


Figure 36c: Line Plot of Pyrene Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	**Statistical Plots of Pyrene Concentrations**	**Figure 36**

µg/kg - microgram per kilogram

Figure 37a: Line Plot of Arsenic Concentrations

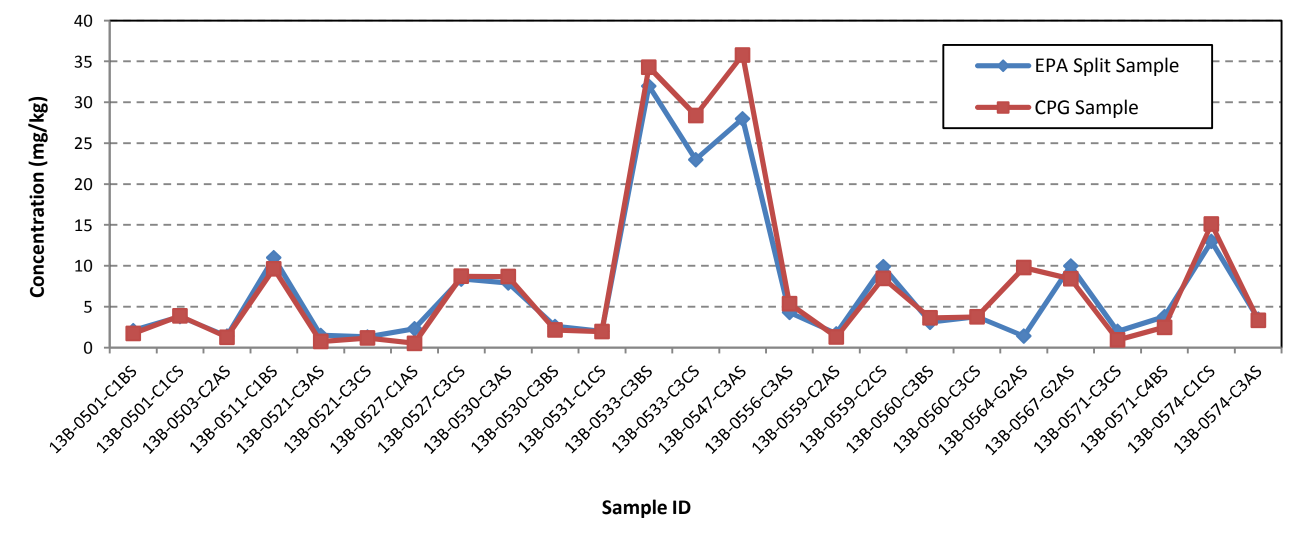


Figure 37b: Bivariate Scatter Plot of Arsenic Concentrations

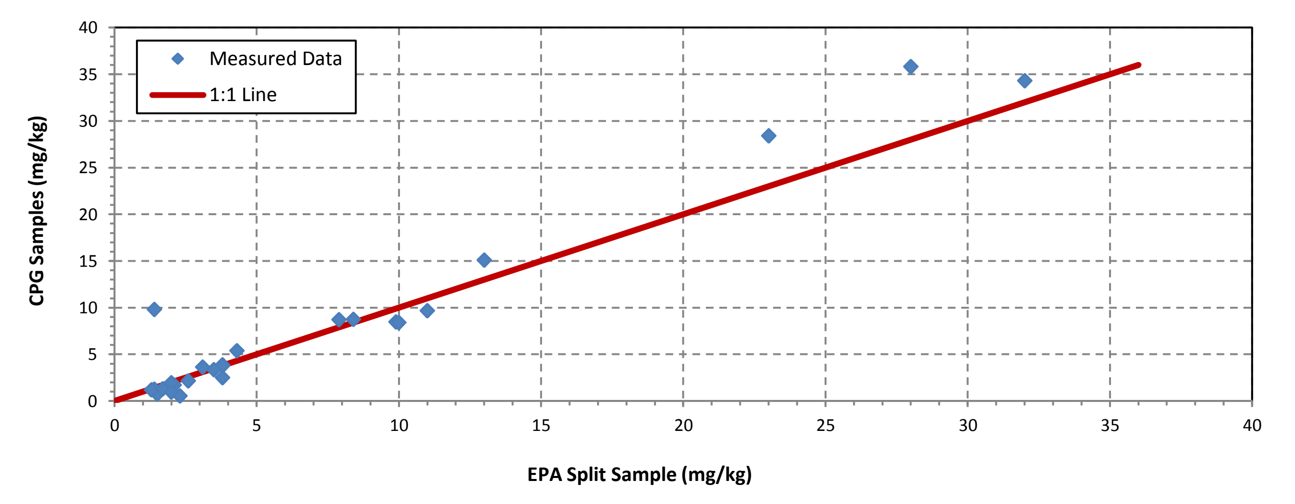
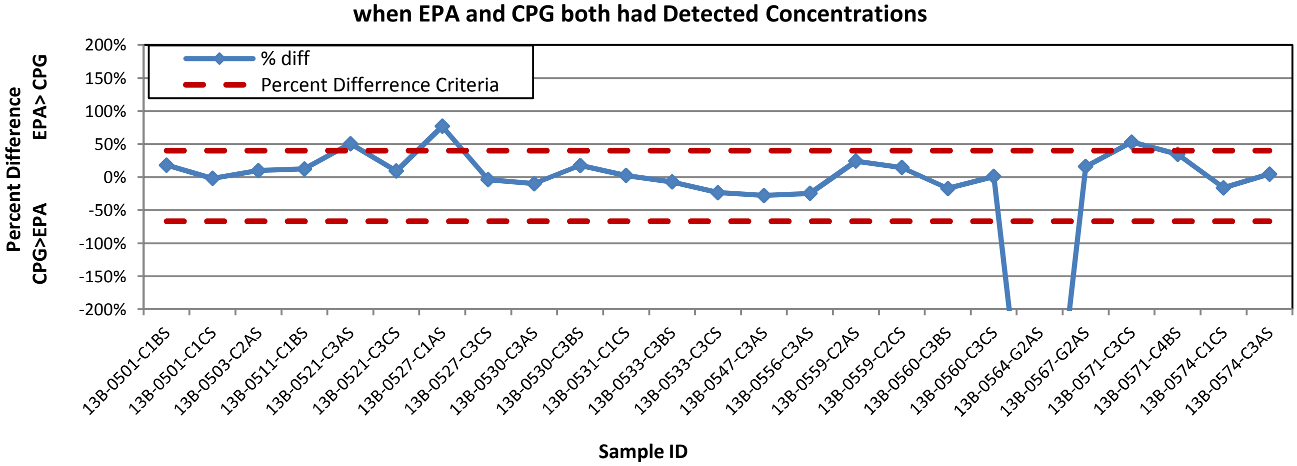


Figure 37c: Line Plot of Arsenic Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of Arsenic Concentrations	Figure 37

mg/kg - milligram per kilogram

Figure 38a: Line Plot of Barium Concentrations

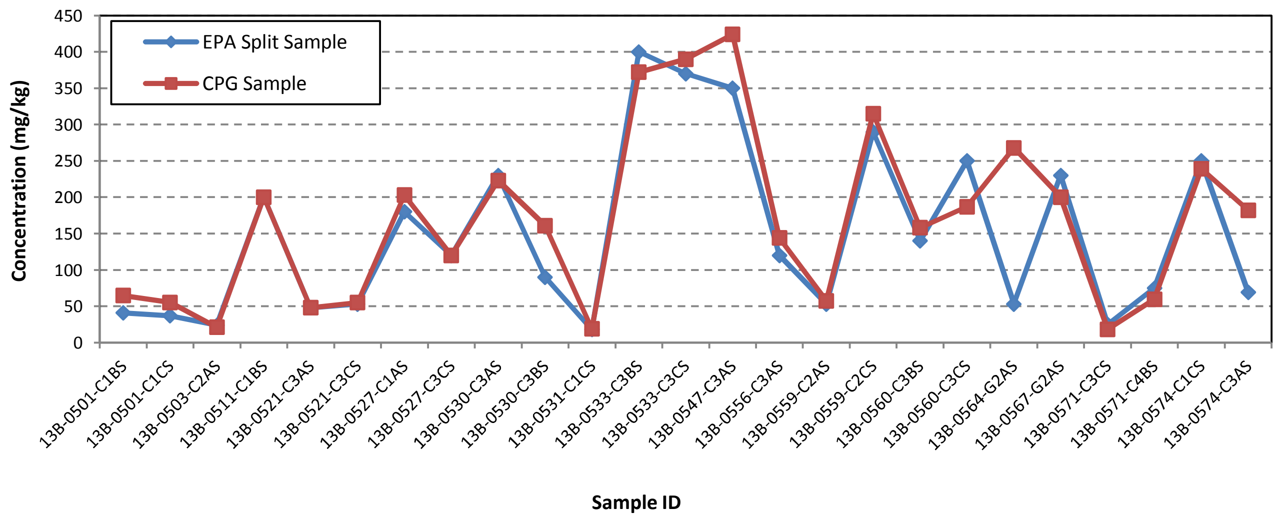


Figure 38b: Bivariate Scatter Plot of Barium Concentrations

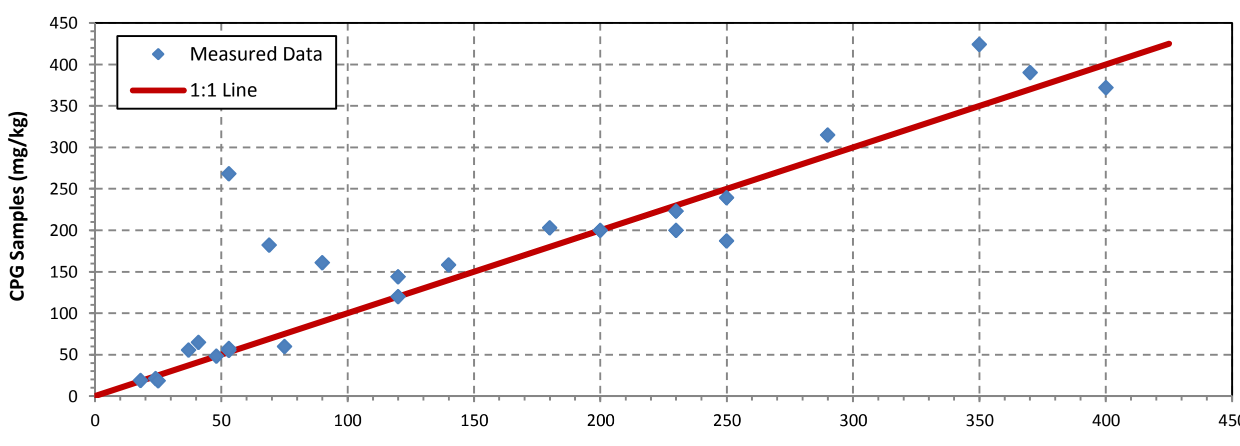
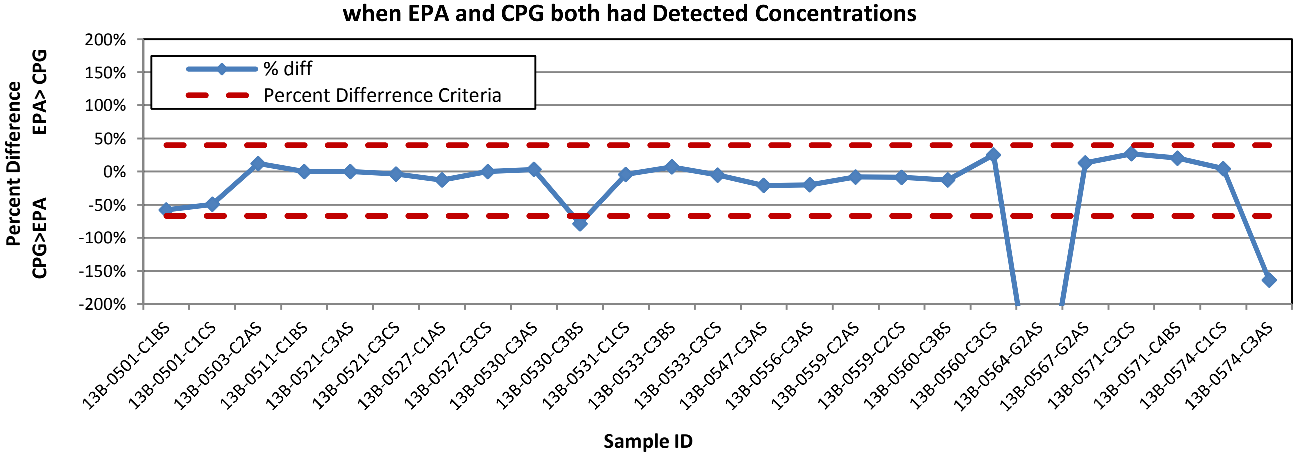


Figure 38c: Line Plot of Barium Percent Differences when EPA and CPG both had Detected Concentrations



	Statistical Plots of Barium Concentrations	Figure 38

mg/kg - milligram per kilogram

Figure 39a: Line Plot of Cadmium Concentrations

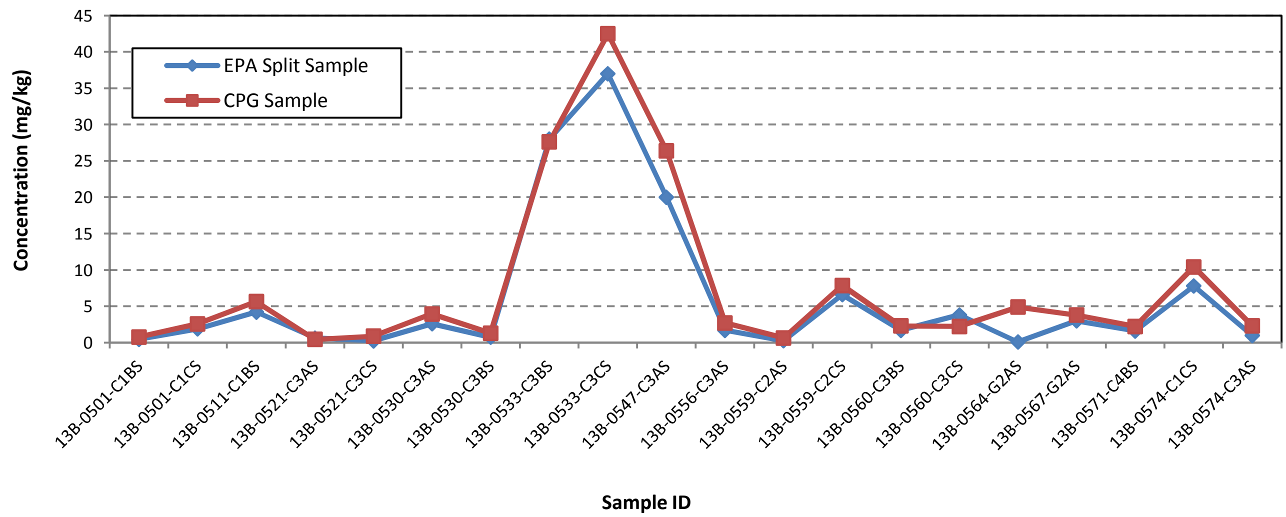


Figure 39b: Bivariate Scatter Plot of Cadmium Concentrations

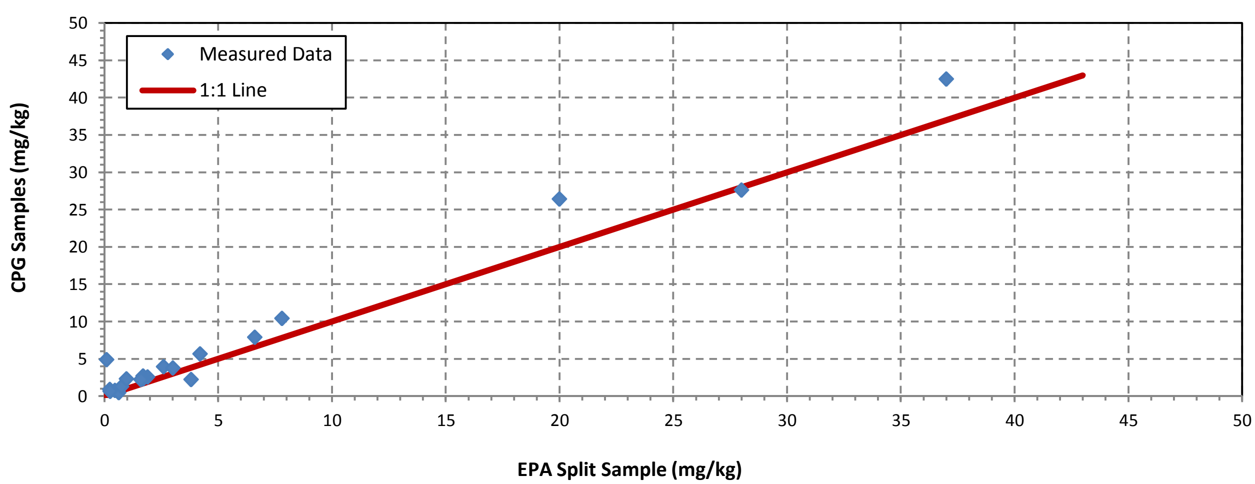
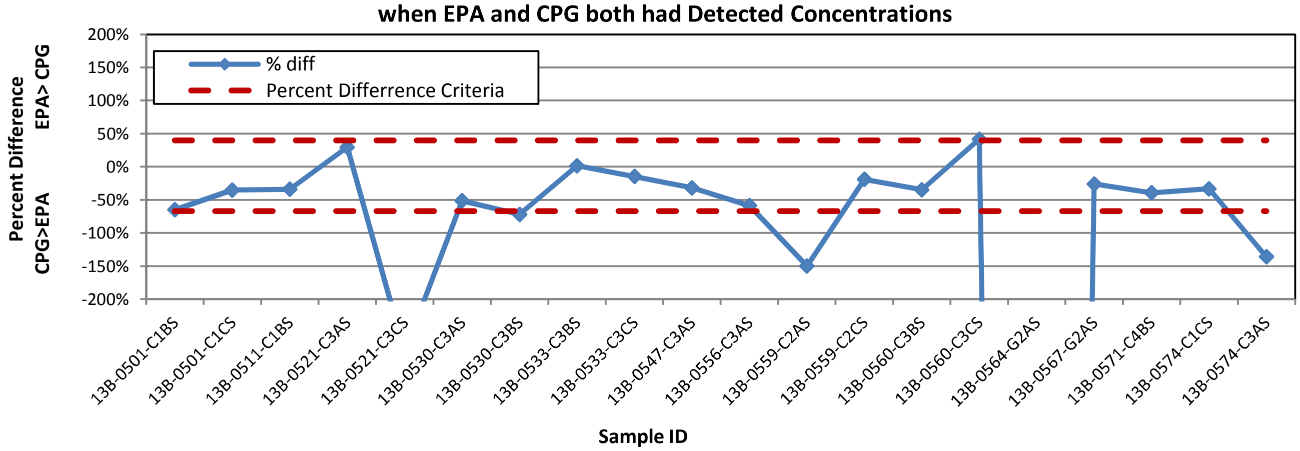


Figure 39c: Line Plot of Cadmium Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers

Statistical Plots of Cadmium Concentrations | **Figure 39**

mg/kg - milligram per kilogram

Figure 40a: Line Plot of Chromium Concentrations

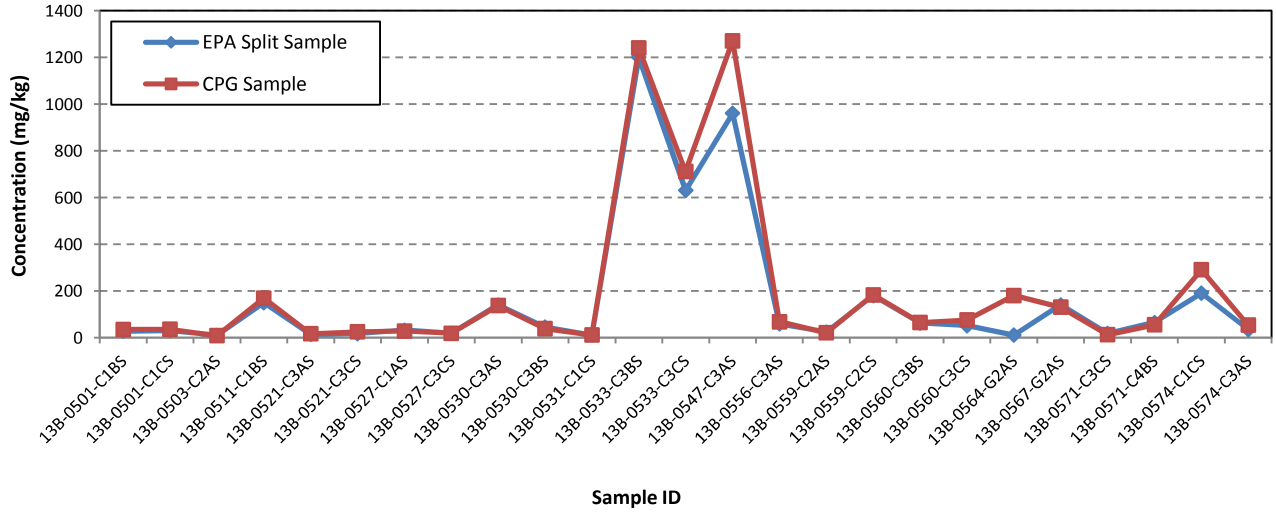


Figure 40b: Bivariate Scatter Plot of Chromium Concentrations

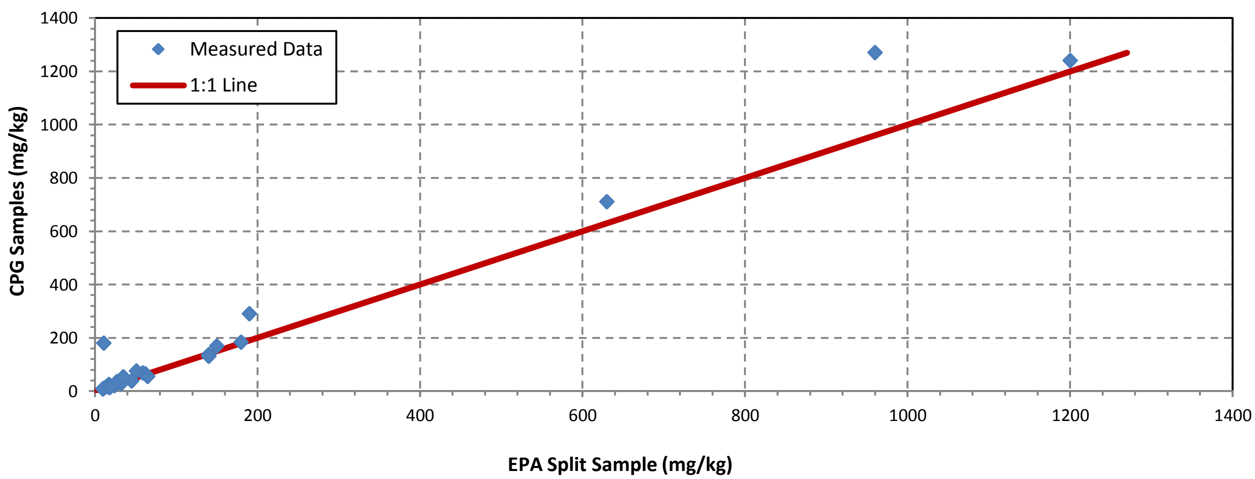
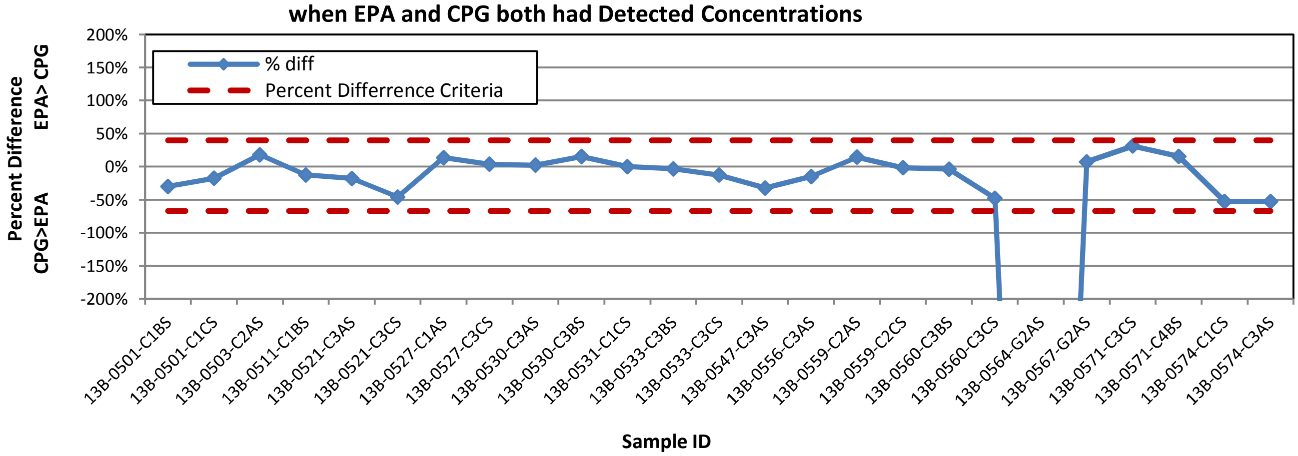


Figure 40c: Line Plot of Chromium Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of Chromium Concentrations	Figure 40

mg/kg - milligram per kilogram

Figure 41a: Line Plot of Cobalt Concentrations

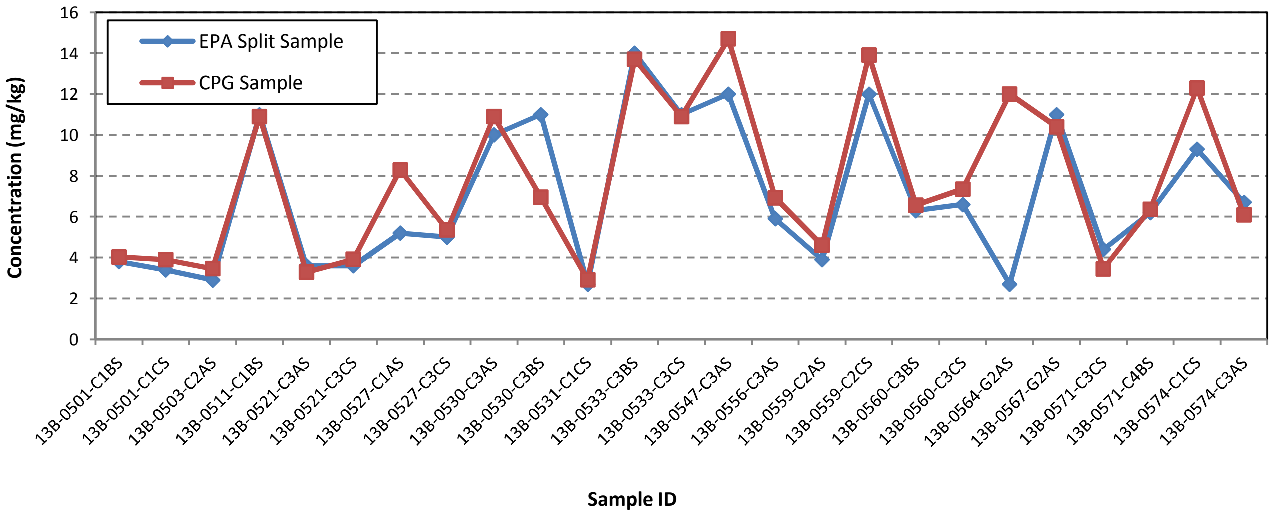


Figure 41b: Bivariate Scatter Plot of Cobalt Concentrations

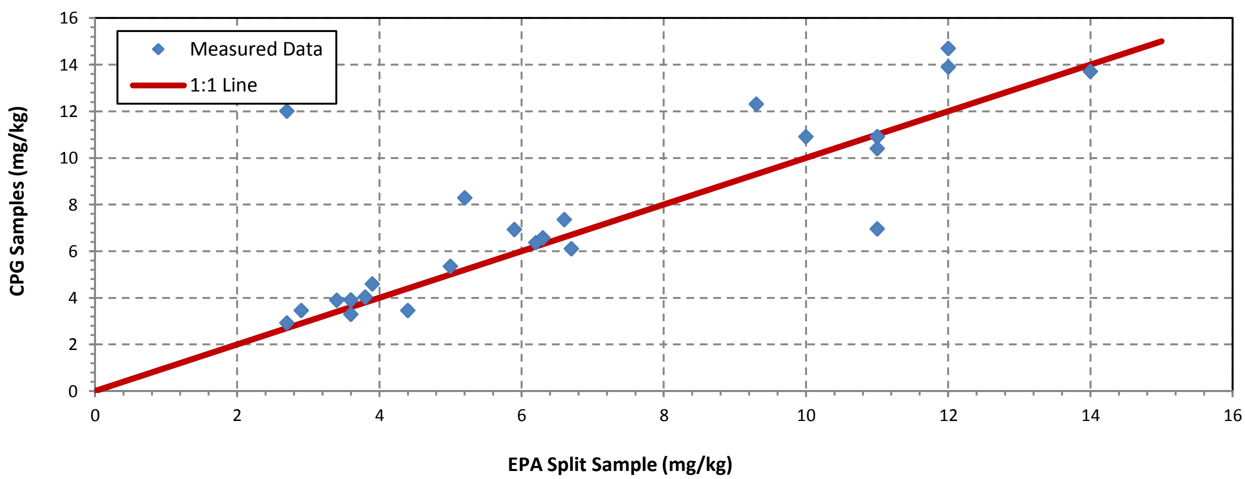
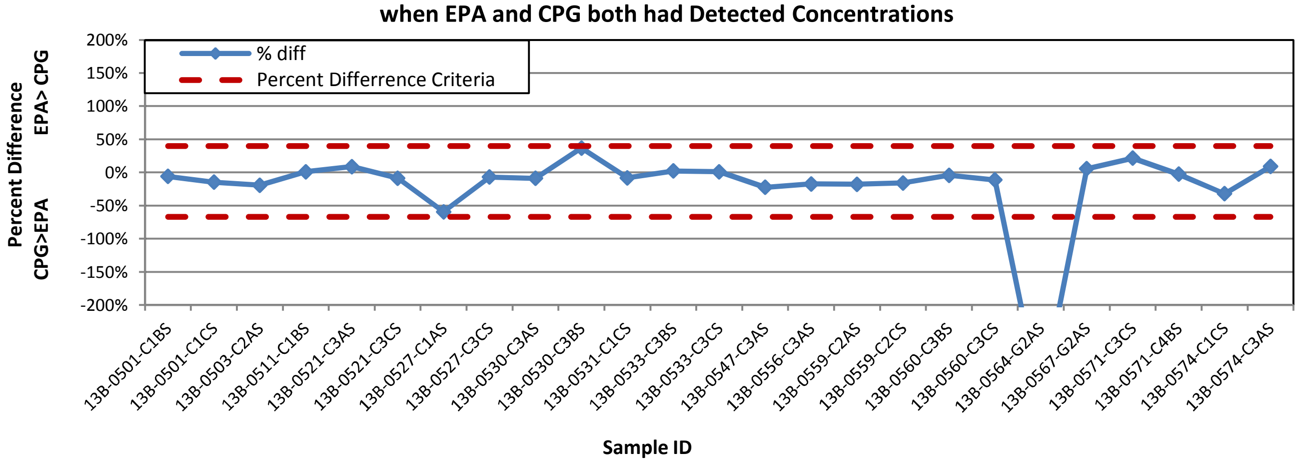


Figure 41c: Line Plot of Cobalt Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of Cobalt Concentrations	Figure 41

mg/kg - milligram per kilogram

Figure 42a: Line Plot of Copper Concentrations

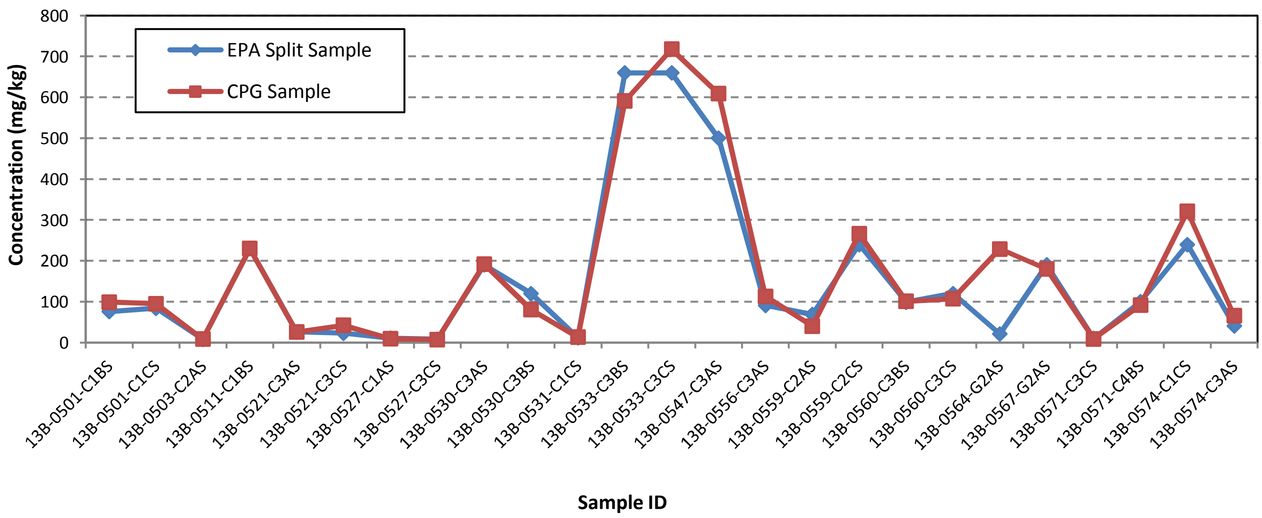


Figure 42b: Bivariate Scatter Plot of Copper Concentrations

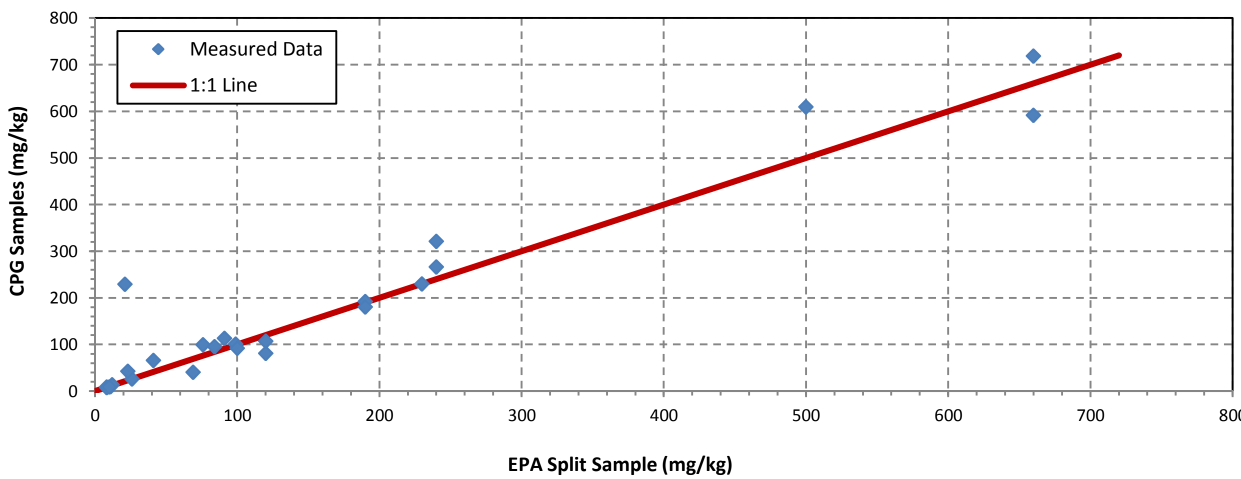
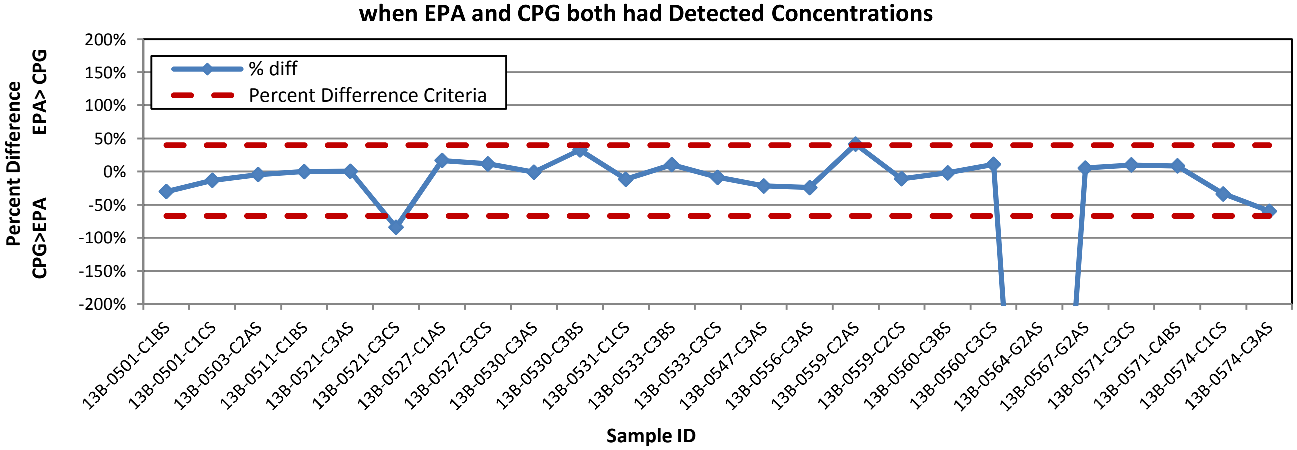


Figure 42c: Line Plot of Copper Percent Differences when EPA and CPG both had Detected Concentrations

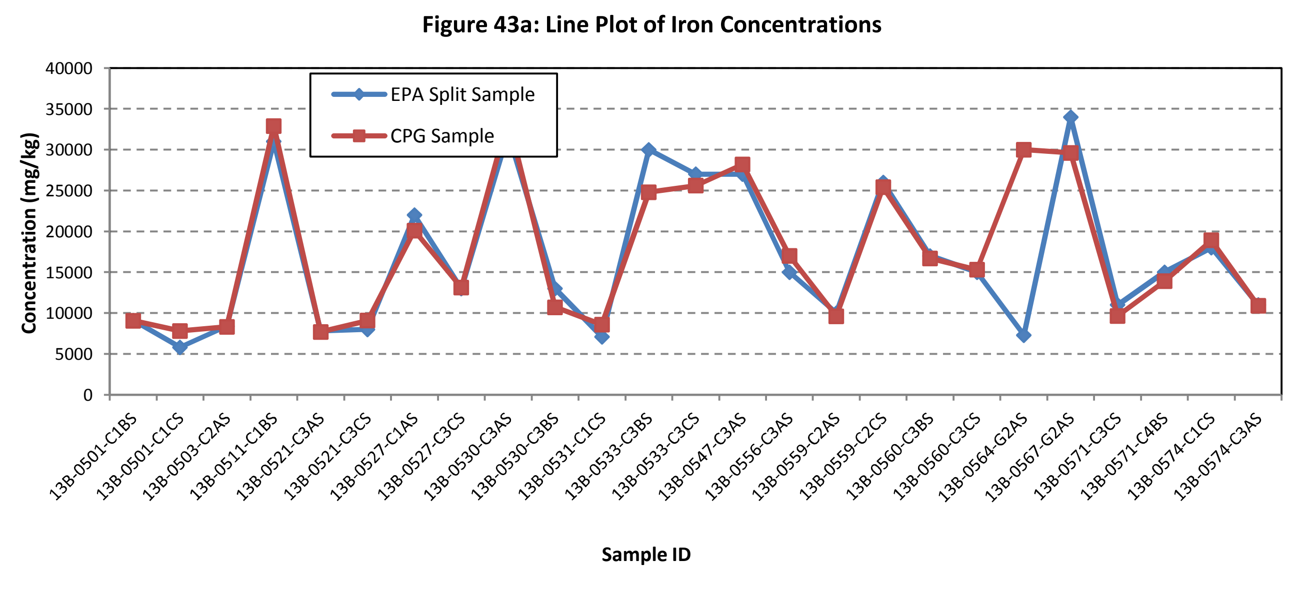


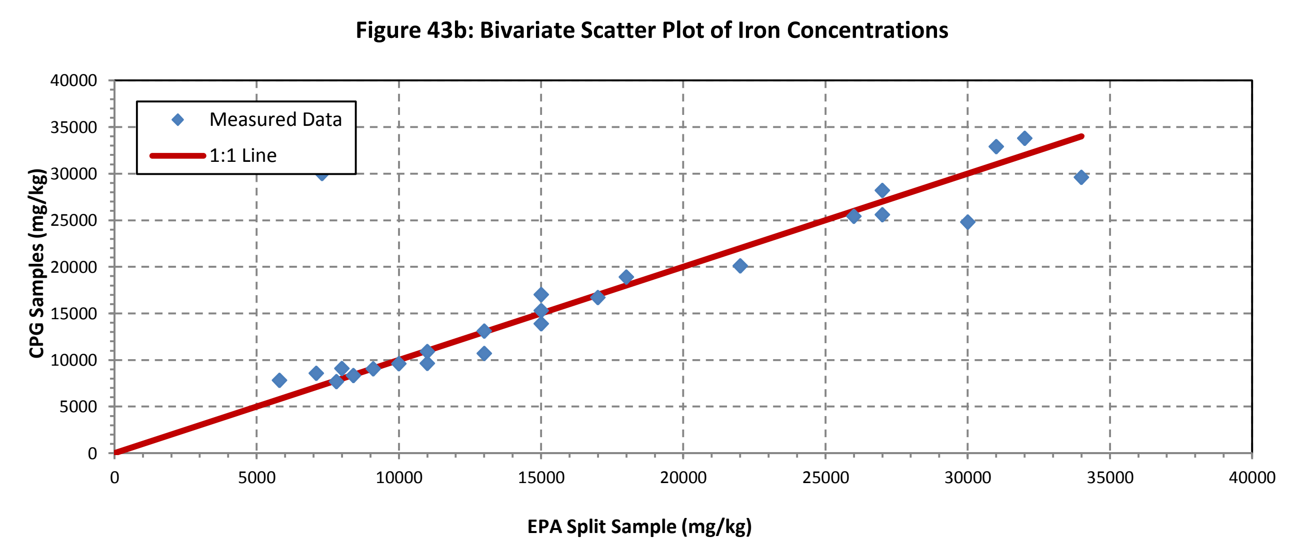
US Army Corps of Engineers®

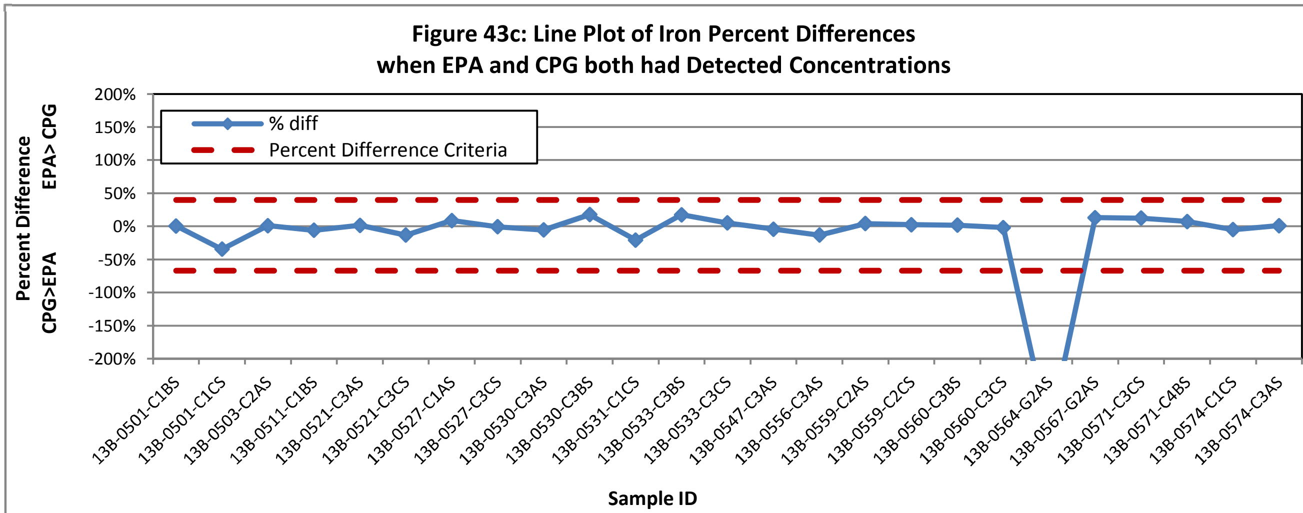
Statistical Plots of Copper Concentrations

Figure 42

mg/kg - milligram per kilogram





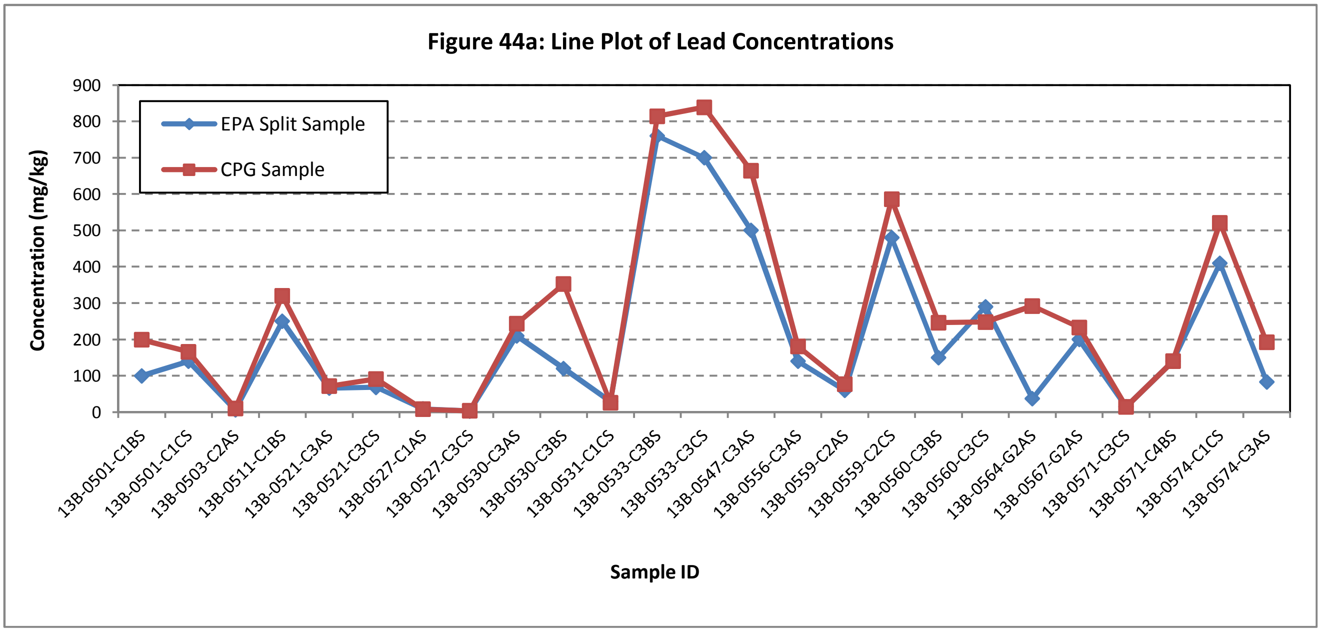


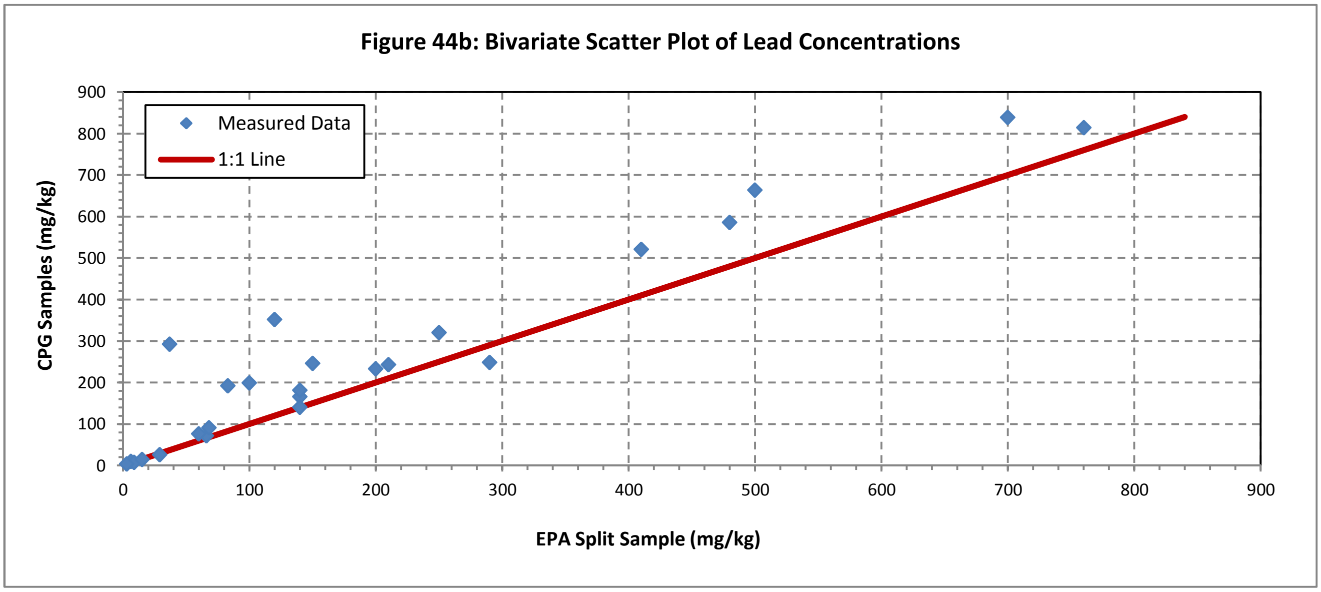
US Army Corps of Engineers

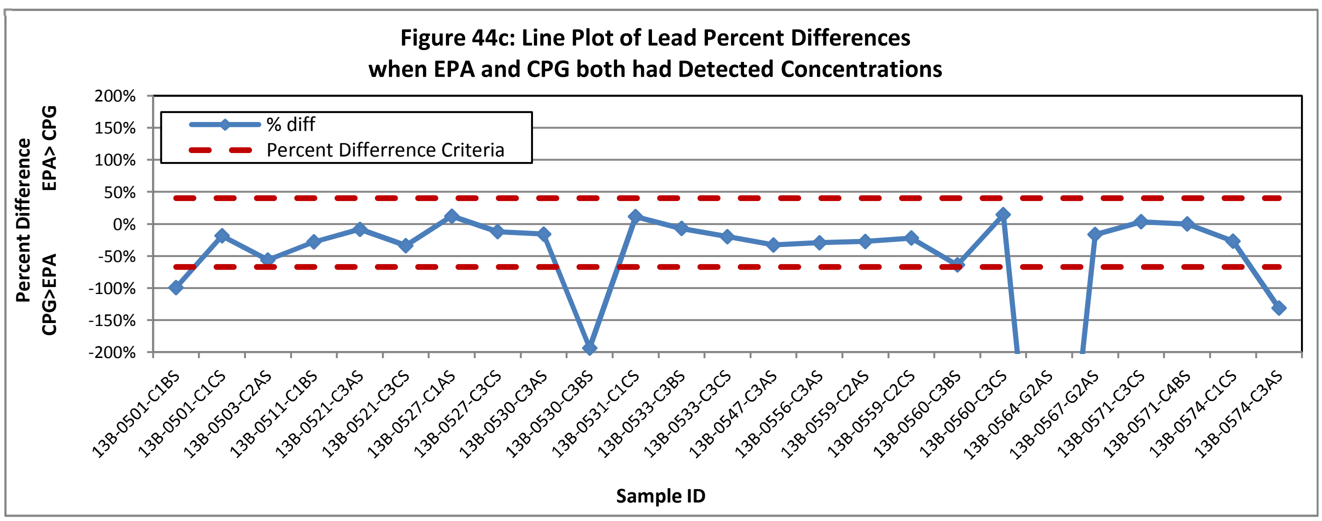
Statistical Plots of Iron Concentrations

Figure 43

mg/kg - milligram per kilogram







US Army Corps of Engineers	Statistical Plots of Lead Concentrations	Figure 44

mg/kg - milligram per kilogram

Figure 45a: Line Plot of Nickel Concentrations

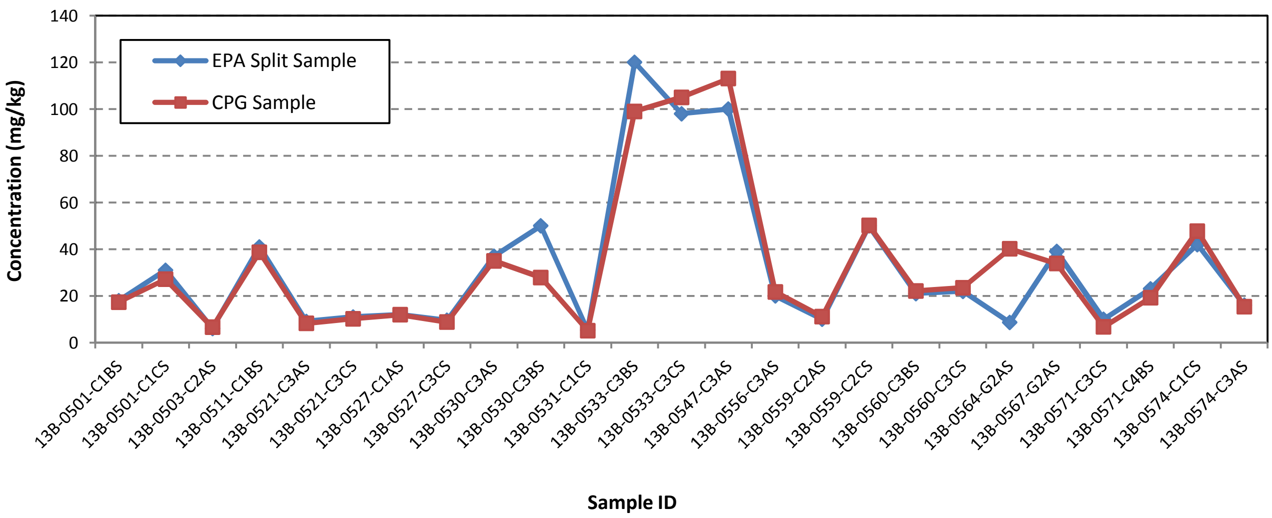


Figure 45b: Bivariate Scatter Plot of Nickel Concentrations

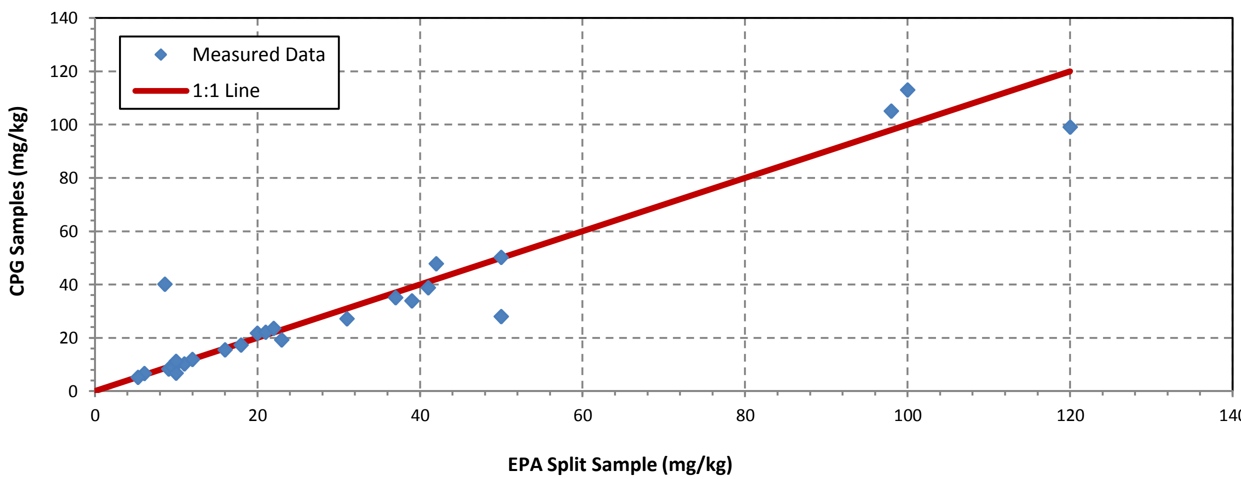
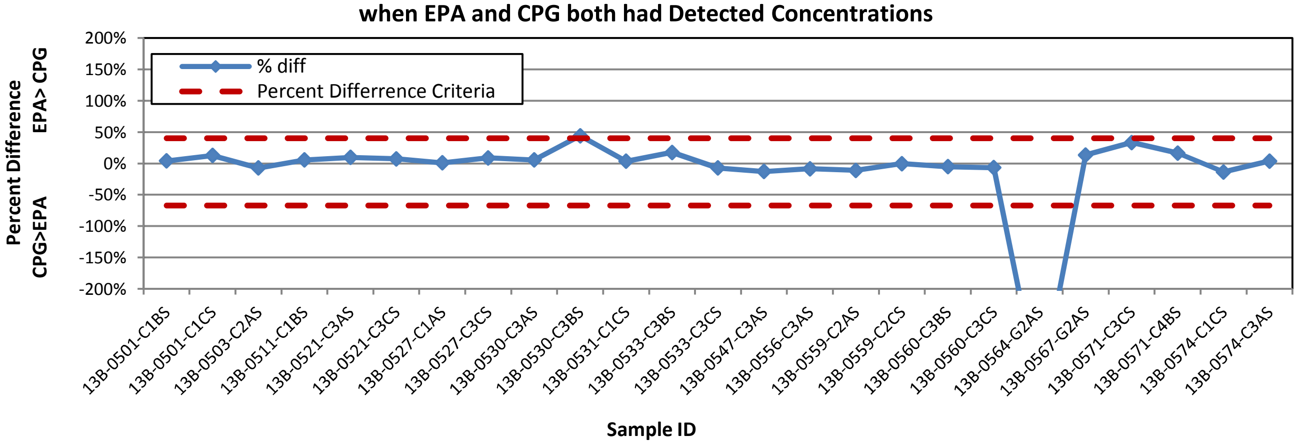


Figure 44c: Line Plot of Lead Percent Differences when EPA and CPG both had Detected Concentrations

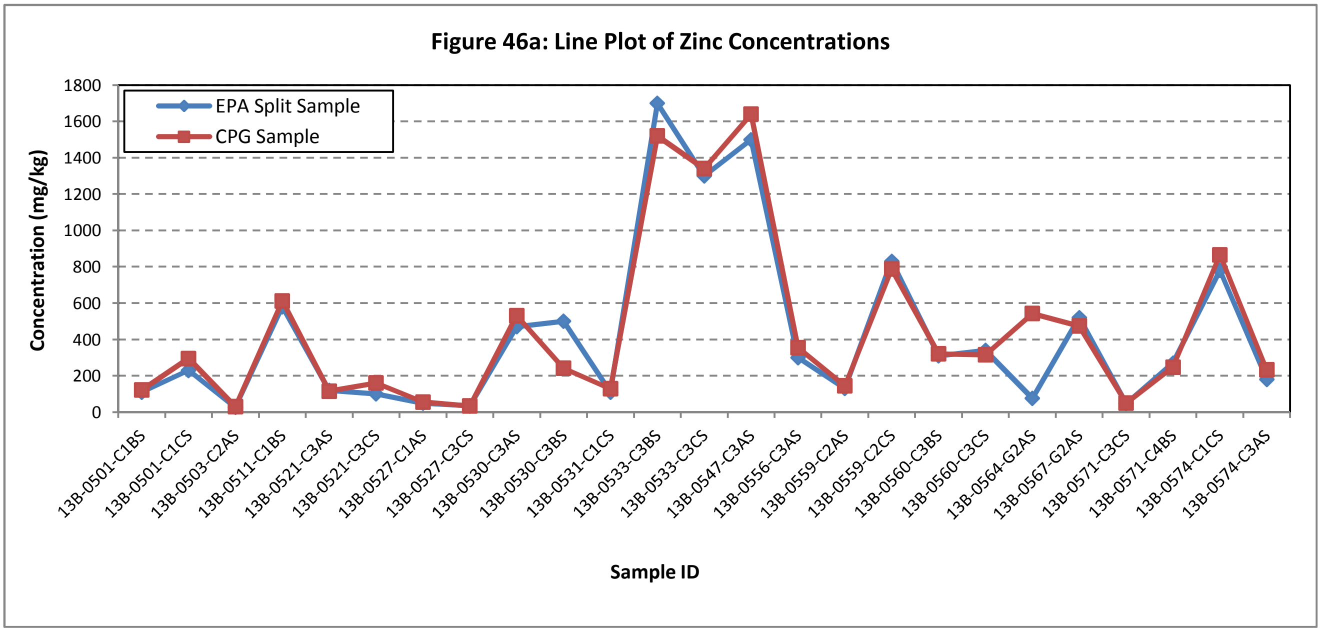


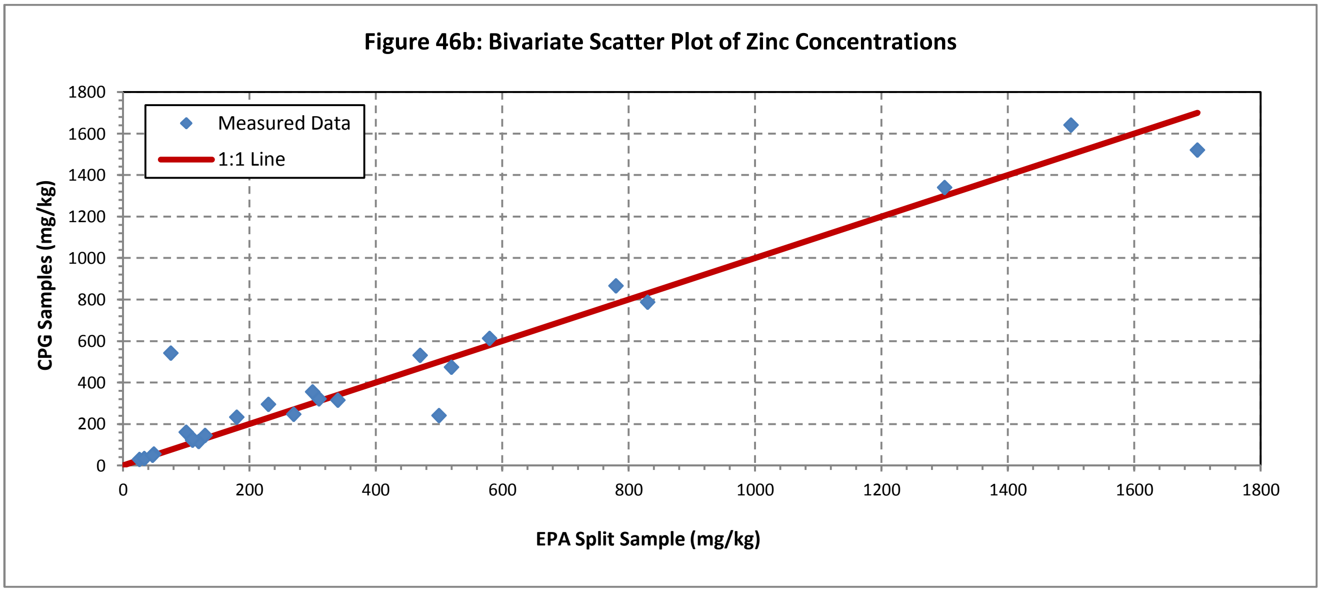
US Army Corps of Engineers®

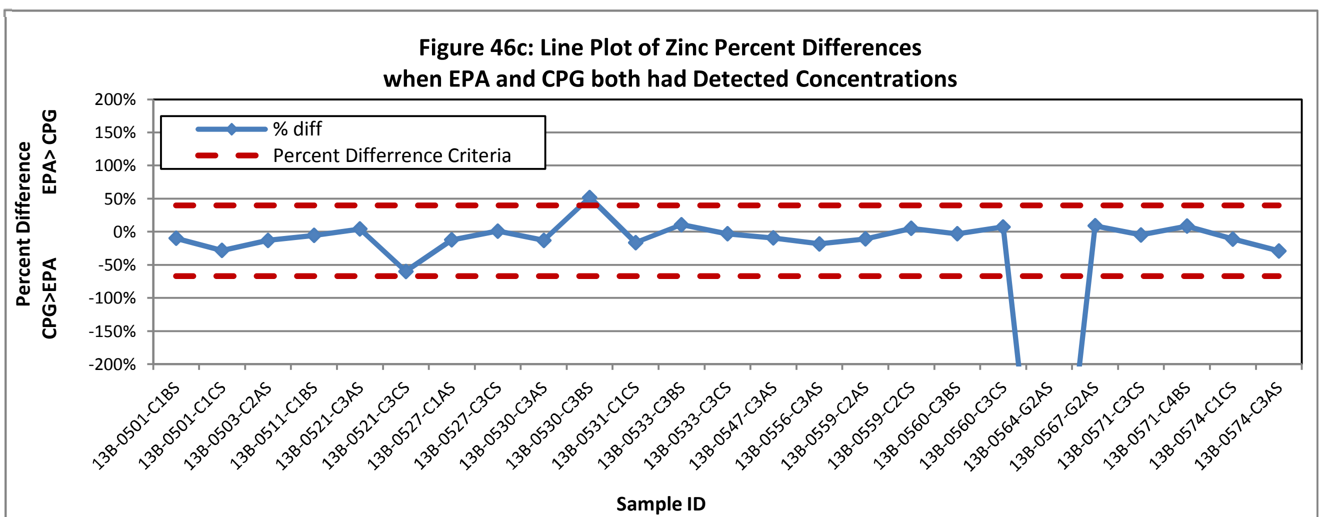
Statistical Plots of Nickel Concentrations

Figure 45

mg/kg - milligram per kilogram

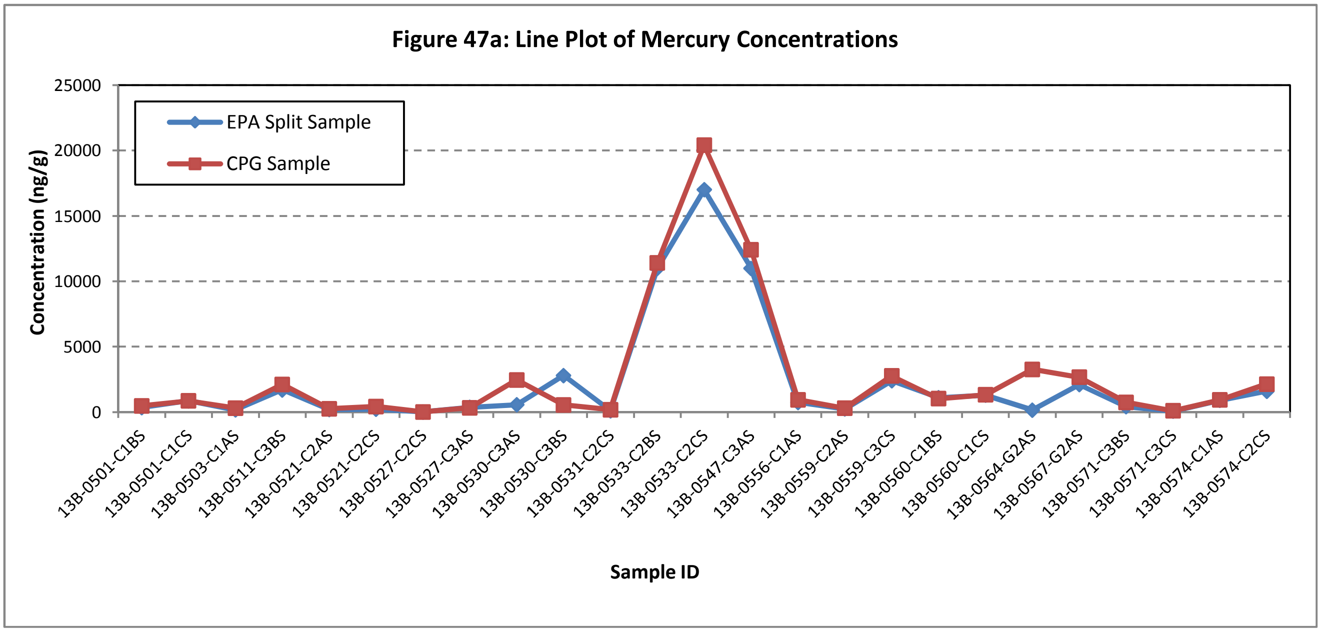


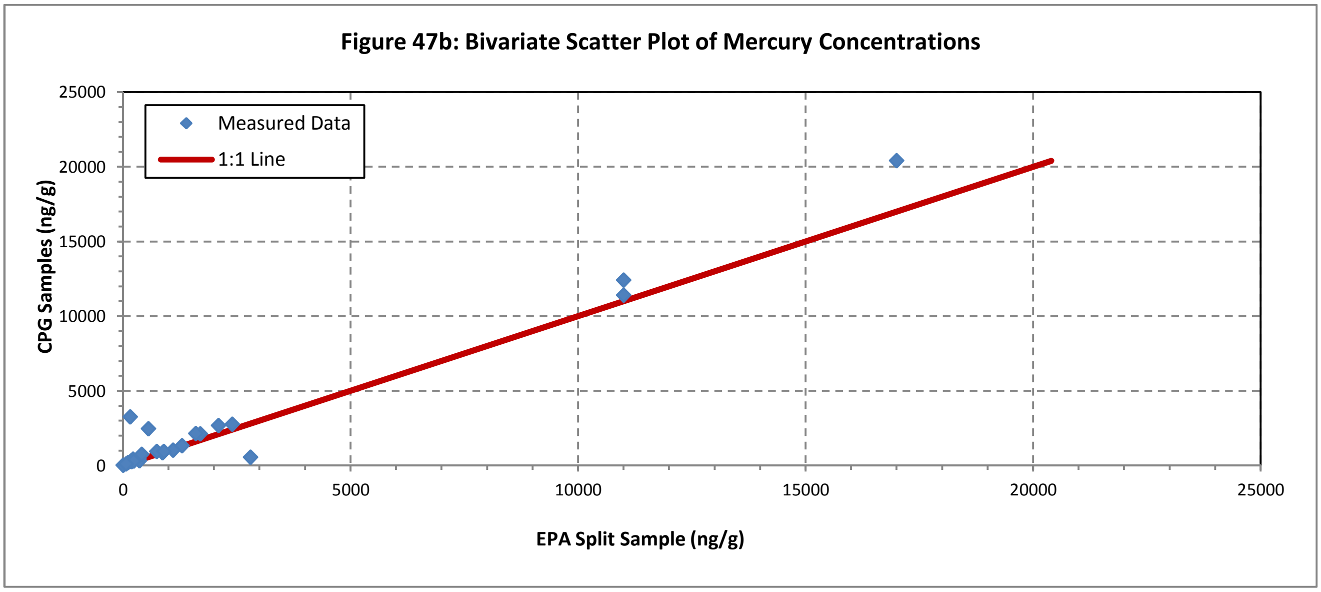


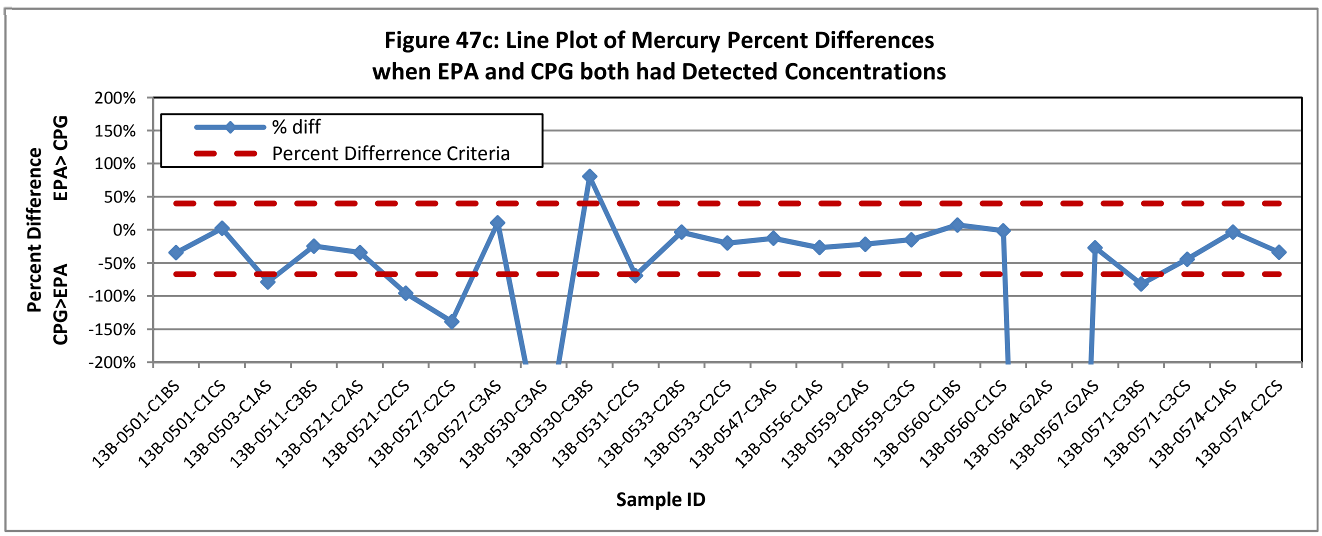


US Army Corps of Engineers®	**Statistical Plots of Zinc Concentrations**	**Figure 46**

mg/kg - milligram per kilogram







US Army Corps of Engineers	**Statistical Plots of Mercury Concentrations**	**Figure 47**

ng/g - nanogram per gram

Figure 48a: Line Plot of Total Organic Carbon Concentrations

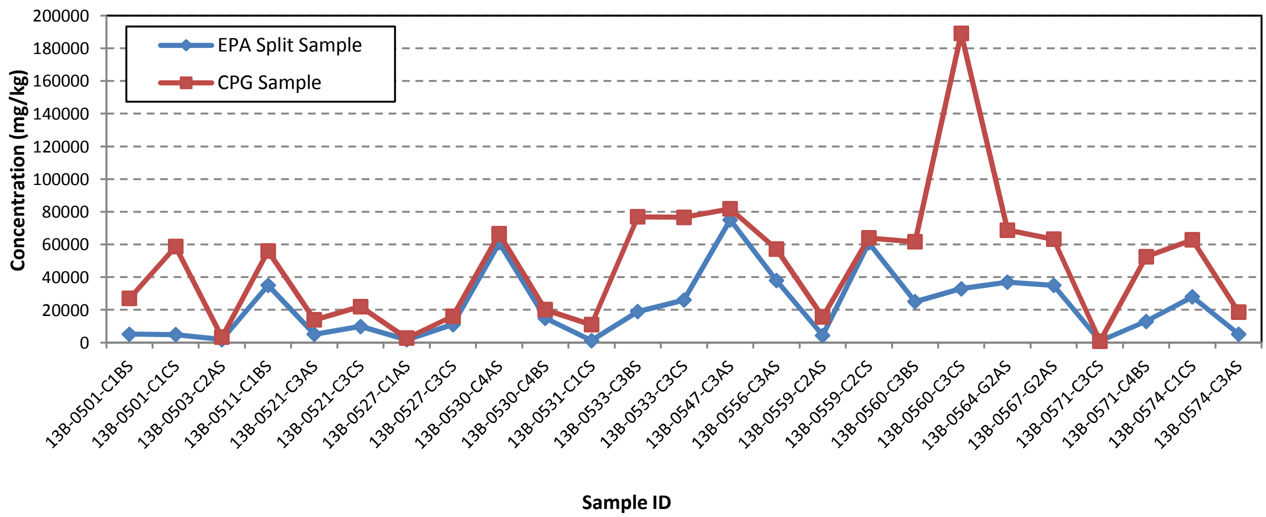


Figure 48b: Bivariate Scatter Plot of Total Organic Carbon Concentrations

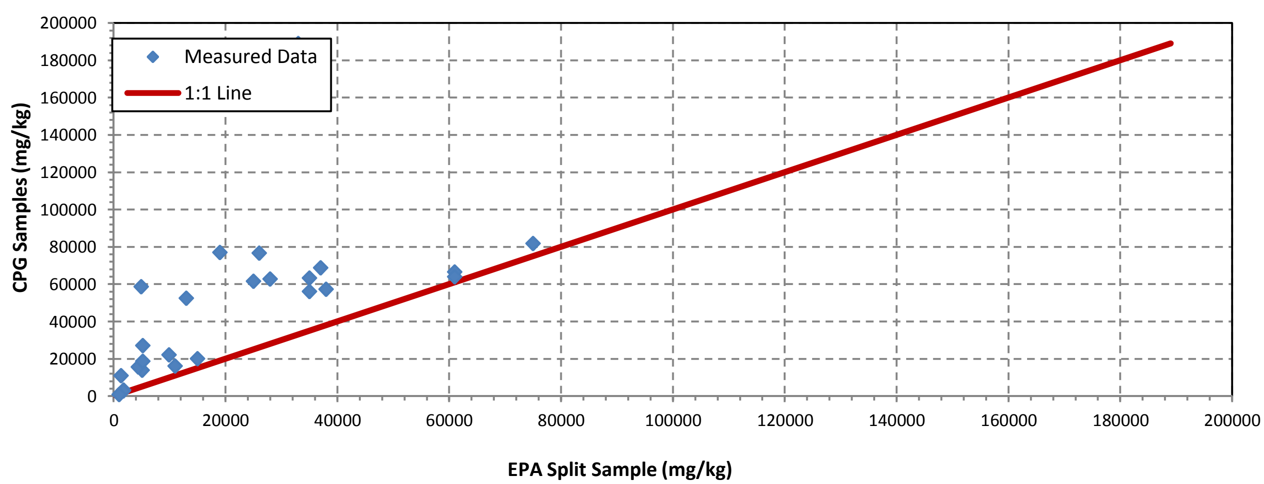
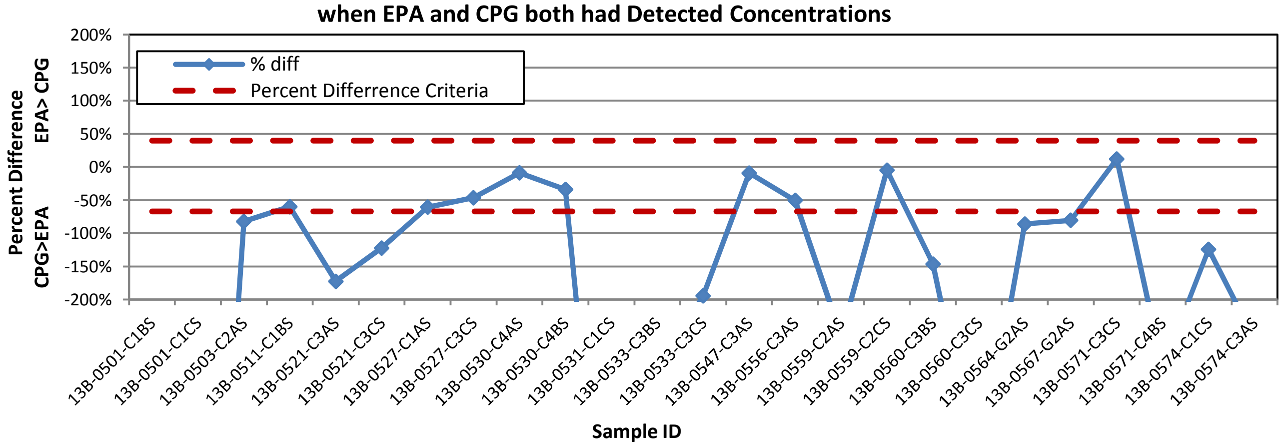


Figure 48c: Line Plot of Total Organic Carbon Percent Differences when EPA and CPG both had Detected Concentrations



US Army Corps of Engineers	Statistical Plots of Total Organic Carbon Concentrations	Figure 48

mg/kg - milligram per kilogram